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NOTES

IN

ENGINEERING 3*a*

HARVARD UNIVERSITY

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CAMBRIDGE, MASS.
1904

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Special acknowledgement is due Professor G. C. ANTHONY, whose Text Book, "Mechanical Drawing," has suggested several of the exercises and problems given in these notes.

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MEMORANDUM

1. Directions in regard to the conduct of the course will be given at the lectures, and, when necessary, will be published in the Bulletin Board. Each student will be expected to note these directions, or, if absent from a lecture, to obtain them from some fellow-student. In any case he will be held responsible for all information given at the lectures or on the Bulletin Board.

2. Special directions given by any of the instructors in regard to the work of the course will be held valid only when accompanied by a written statement on the sheets, or on suitable blanks. Oral instructions cannot be verified, and will, therefore, be given no consideration.

3. Reporting at either early or final Roll Call explicitly implies the understanding that a student has been in continuous attendance from the opening of the period until the time of the Roll Call. Every student should see that a date stamp is placed on his sheets for each day of attendance.

4. Men who report at early Roll Call will be marked present, on condition that their current work is ready, *in advance*, and, further, that all previous series have been completed on time. The early Roll Call is offered as a privilege, and those who avail themselves of it must accept the entire responsibility of completing their work on time. No exception will be made to this rule.

5. A student who has been signed off at the office can have his attendance record in this course corrected by bringing a memorandum suitably endorsed by the office. This memorandum, to be valid, however, must be presented *not later than one week* after the date of signing on.

6. All work, to be accepted, must be handed in at the appointed times by the student personally, and not by proxy.

7. A date set for overdue work will be considered final. No work presented after that date will be accepted, unless previous agreement in writing has been made.

8. Each student is strongly advised to place an identifying mark on all his materials, including drawing instruments. All instruments and materials are left in the lockers during the year at the student's own risk, and *must* be removed from the lockers on or before the date set for the final examination. All articles not removed will be considered abandoned, and will be treated accordingly.

9. Tests will be held from time to time during the year. The results of these tests will have a very considerable weight in judging the work of the course. No make-ups will be given, but, in special cases where a student is unable to be present at the time of a test, he may make arrangements to take it *in advance*. Unsatisfactory work in the tests *may* serve as a ground for failure in the course, without regard to the quality of the drafting work.

SHEET A

General Instructions

Method of laying out Drawing Sheet — Use of Materials

SHEET A — GENERAL INSTRUCTIONS

METHOD OF LAYING OUT DRAWING SHEET — USE OF MATERIALS

DIRECTIONS

I. Fold and cut sheet into 4 equal parts.

The kind of paper used in this course is known as "**Duplex.**"

II. Thumb tack one part to Drawing Board. (One thumb tack in each corner.)

III. *Fig. 10.* With **T**-square laid across corners draw *short, light* lines **AB** and **CD**, thus finding approximate centre of sheet. (**Use 6 H Pencil.**)

IV. *Fig. 11.* With **T**-square draw **EF** (*light*) through centre. With *Triangle* draw **GH**. These are called "**Centre Lines**" of sheet.

V. *Fig. 12.* Along *Centre Lines* lay off **9** *inches* and **6** *inches*, respectively, either side of centre. (Use *Triangular Scale* as shown.) With *T*-square and *Triangle* draw rectangle as shown. This is called "**Cutting Line.**"

VI. *Fig. 13.* Again, lay off **8** *in.* and **5** *in.* on Centre Lines and complete second rectangle. This is called the "**Border Line.**"

VII. *Fig. 14.* The result is a sheet as shown; **18** *in.* by **12** *in.* (*outside measurement*) with **1** *inch* Border all round. This is called the "**Layout of Sheet.**"

NOTES

A. **Pencil.***

(*a*) **6 H** pencil sharpened, on *Sand Paper* pad, with *chisel* point. (*Fig. 1.*)

Used always for *Laying out Sheet* and *Blocking out Drawings*.

(*b*) **2 H** pencil sharpened, on pad, with *round* point. (*Fig. 2.*)

Used always for *Strengthening Outlines* and *for Lettering*.

(*c*) **Compass** pencil sharpened as in — (*Fig. 3.*)

Use **6 H** for Blocking out; **2 H** for Strengthening.

Use small *Needle Point* end in other leg of compasses. (*Fig. 4.*)

B. **Pen.**

(*a*) Have *both nibs* touching paper (*Fig. 5*), not (*Fig. 6.*)

(*b*) *Do not fill pen too full.*

(*c*) *Clean* pen often with pen-wiper.

C. **T-Square.**

(*a*) Always use *T-square* at *Left* end of board. (*Fig. 7.*)

If left-handed, change to Right end.

(*b*) Always draw along *upper* edge of *T*-square.

D. **Triangles.**

(*a*) Always use *triangles* on *top edge* of *T*-square.

Wherever possible draw with light coming from Direction (**A**). (*Fig. 7.*)

(*b*) To draw *Parallel* lines, slide triangle along Straight Edge (either *T*-square or another triangle). (*Fig. 8.*)

(*c*) To draw *Perpendicular* to a given line, place triangle against a Straight Edge, as shown in *full lines;* then turn triangle to *dotted* position, slide along to required point and draw perpendicular **CD**. (*Fig. 9.*)

* Whenever possible draw lines from **Left** to **Right** and from **Bottom** towards **Top** of sheet.

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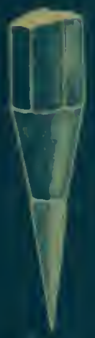
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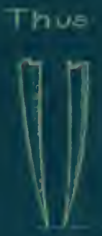

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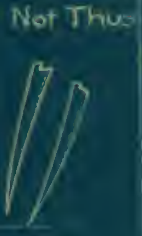

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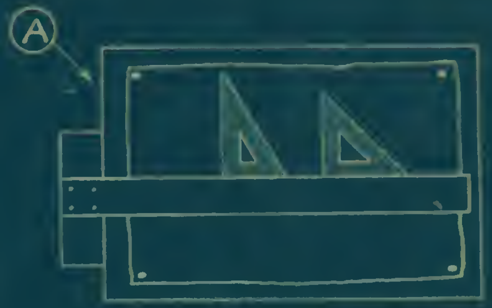

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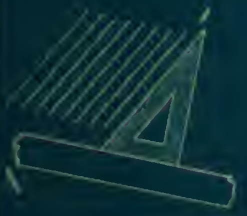
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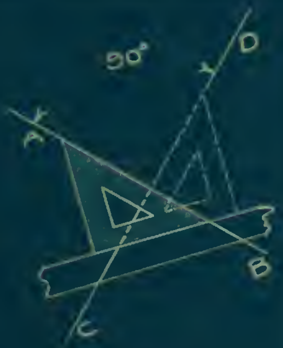

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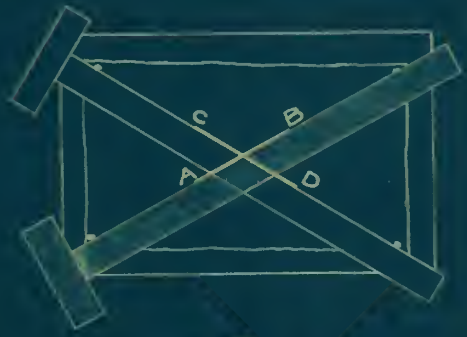

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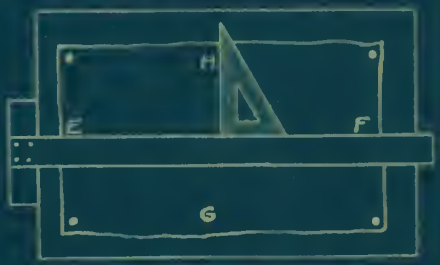

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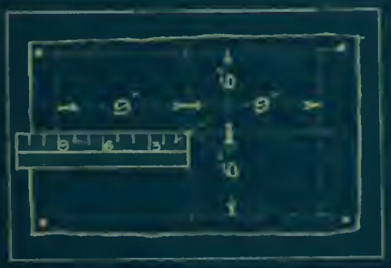

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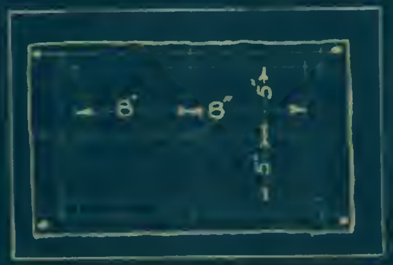

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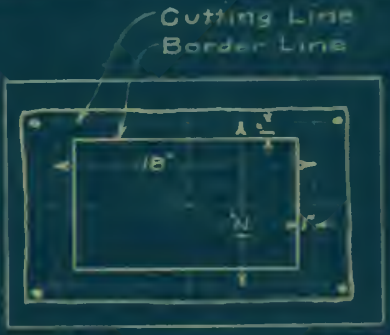

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SHEET 1

Lettering

SHEET 1 — LETTERING

DIRECTIONS

I. Lay out sheet as explained. (Page *2*.)

II. Place your number (in *black* ink) in the upper right hand margin of sheet.

III. Draw all *guide lines* for letters, *very light*, spaced as shown and with **6 H** pencil. (Sharpened. See Page *2–A–a*.)

IV. (*a*) Copy *freehand* the letters and figures indicated. Consult Sheet *F*, Page *80*, for form of letters.

(*b*) Use **2 H** pencil. (Sharpened. See Page *2–A–b*.)

(*c*) Press lightly.

(*d*) Make all letters *Vertical* as in copy.

(*e*) Make letters *round* and *full*.

(*f*) *Do not crowd.*

V. Add Title.

(*a*) Draw base line for title $\frac{1}{2}$ *inch* below *Border Line*.

(*b*) Begin title far enough to the left to end exactly under (**A**).

(*c*) To do this block out the title on a separate paper to determine length required.

NOTES

A. All statements enclosed in *Rectangles* are to be omitted from the drawing sheets.

They are for direction only.

B. The lettering used in this course is an adaptation of the "*Reinhardt*"* **Gothic Alphabet.** Make the *small* letters $\frac{1}{8}$ *inch* high; the *capitals* and *figures* $\frac{3}{16}$ *inch* high.

This size will be called "**Standard,**" and will be used for general lettering throughout the course.

In *fractions* make numerator and denominator figures each about $\frac{2}{3}$ standard size.

C. The location and arrangement of title on Sheet 1 will be called the "**Standard Title,**" and will be used on all sheets of this size.

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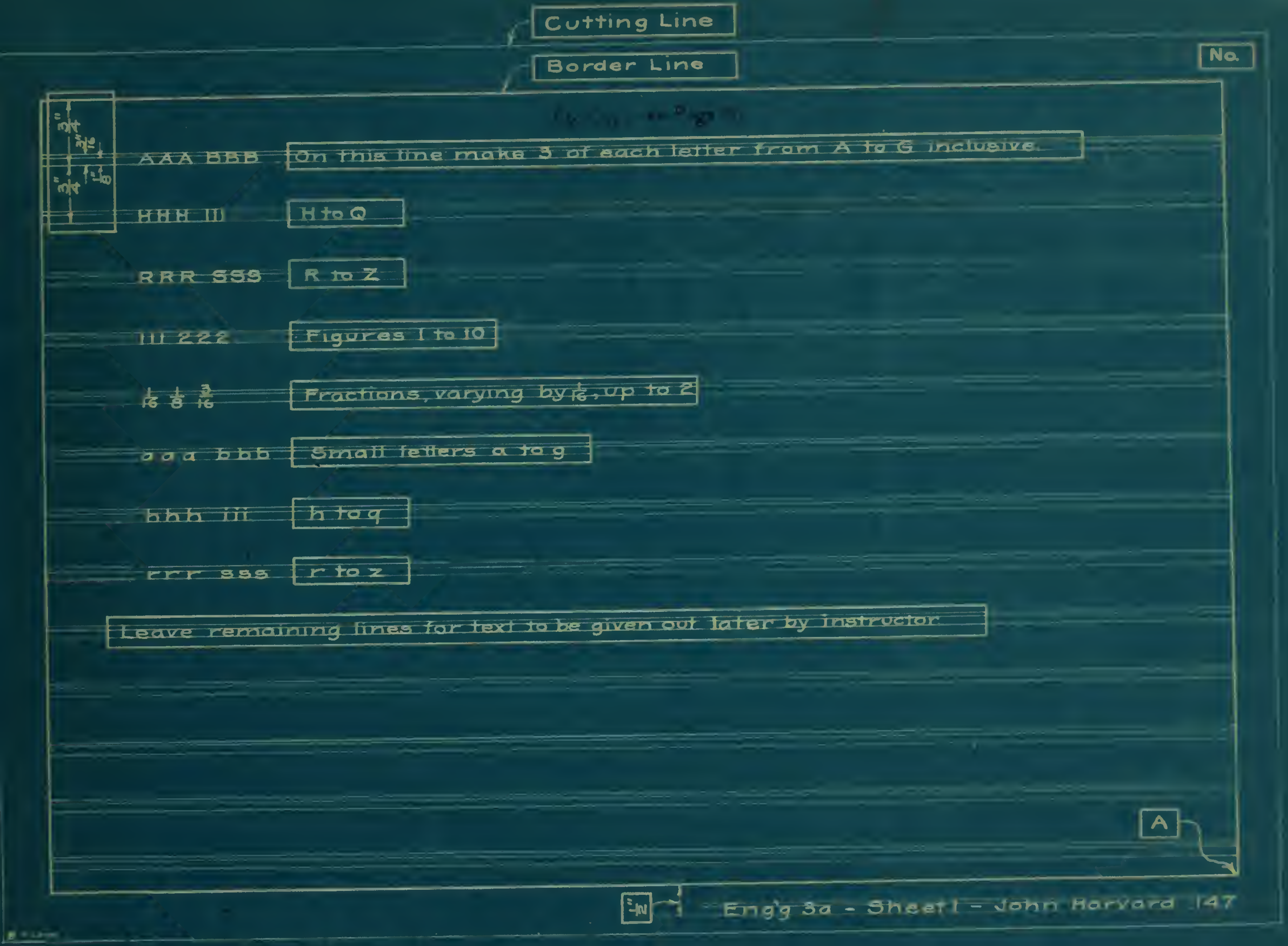
* See "*Lettering*" by Chas. W. Reinhardt.



On this line make 3 of each letter from A to G inclusive.

H to Q

R to Z

Figures 1 to 10

Fractions, varying by 1/16, up to 2"

Small letters a to g

h to q

r to z

Leave remaining lines for text to be given out later by instructor

Sheet 1

SHEET 2

Practice in Pencil Lines

SHEET 2—PRACTICE IN PENCIL LINES

DIRECTIONS

I. *Upper Left.* HORIZONTAL LINES.

(*a*) Space off with scale along *Vertical Centre Line* of sheet.

(*b*) Begin at *Top* and work down. (Use *T*-square.)

II. *Upper Right.* VERTICAL LINES.

(*a*) Space off along *Horizontal Centre Line.*

(*b*) Begin at *Left* and work to *Right.* (Use *T*-square and *Triangle.*)

III. *Lower Left.* SLANTING LINES.

(*a*) Use *T*-square and *45° Triangle.*

IV. *Lower Right.* **Parallel Lines.**

(*a*) Draw Parallelogram **ABCD**.

(*b*) *Outside* draw lines parallel to **AB**.

(*c*) *Inside* " " " " **BC**.

(Use Method given on PAGE *2–D–b.*)

V. Add *Title* and *Number* as in SHEET *1*.

NOTES

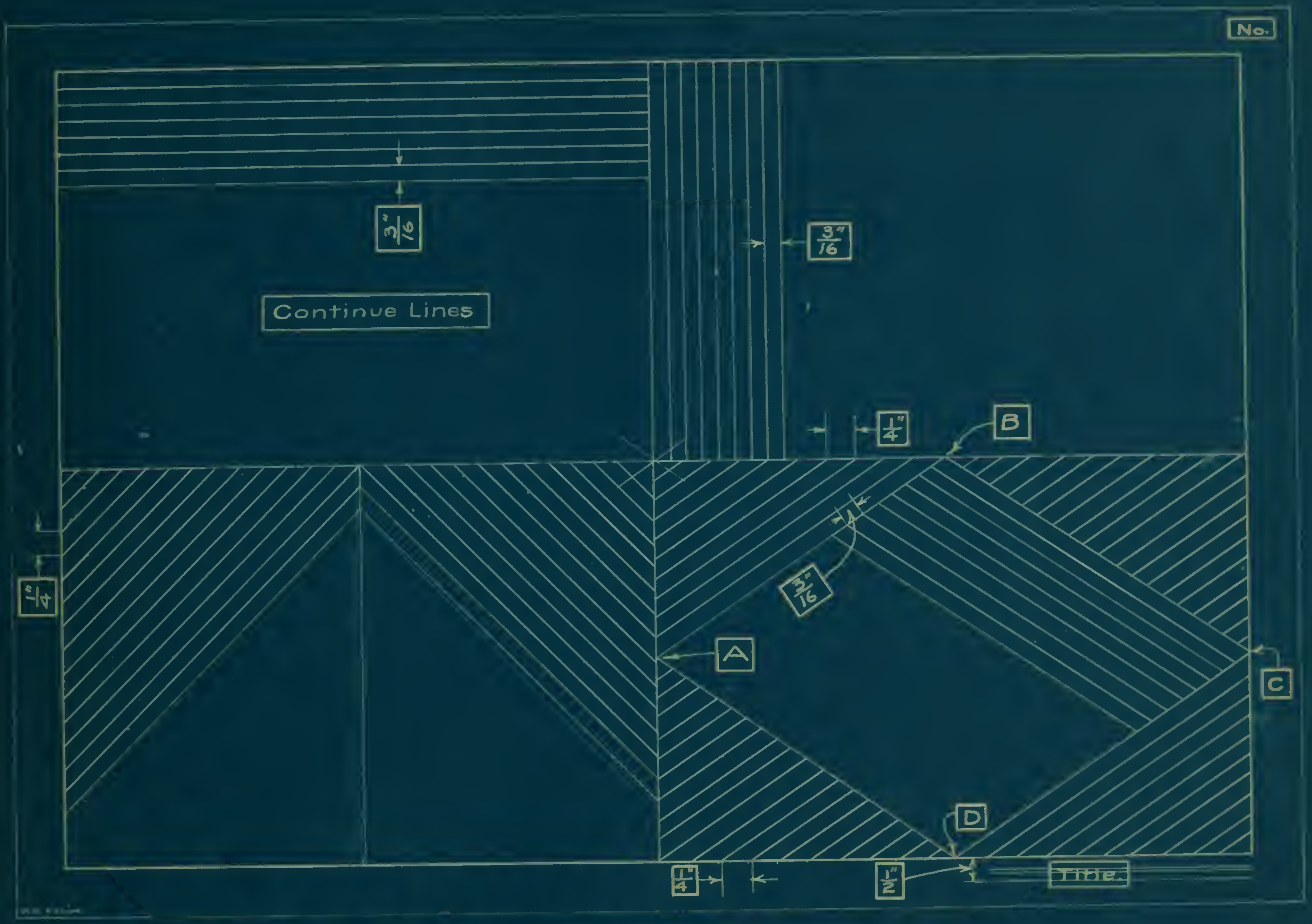
A. Lines to be:—

(*a*) **Fine.**

(*b*) **Uniform.**

(*c*) **Accurately drawn.**

(Use **6 H** pencil; sharpened. See PAGE *2–A.*)



Sheet 2.

SHEET 3

Practice with Instruments

DIRECTIONS

I. *Ex. 1.* Given 2 Circles, *3 inch* diam. and *4 inch* diam., respectively.

Circumscribe Hexagons.

The larger with one flat side horizontal, the smaller with one flat side vertical.

Use *T*-square and *60°* Triangle *only.*

II. *Ex. 2.* Given Circle 3½ *in.* diam.

(*a*) Draw lines *15°* apart as shown. Use *T*-square, **45°** and **60°** Triangles *only.*

(*b*) On left half of Circle draw *Tangent* at end of *every other line* by method of 2 Triangles. See Page *2–D–c.*

(*c*) On right half of Circle draw *Tangents* at end of *any 3* lines by geometry.

See note at bottom of Sheet *3.*

III. *Ex. 3.* Given Circle 3½ *in.* diam. Lay off angles as shown. (Use *Protractor.*)

Do not add arrows or figures.

IV. *Ex. 4.* Given Line at angles of 37½° with Horizontal. (Use *Protractor.*)

On this line as base draw a regular *Hexagon,* each side = 1½ *inch.*

V. *Ex. 5.* Given Circle 3¼ *in.* diam. Inscribe a regular *Pentagon.* (See Page *81–8.*)

VI. *Ex. 6.* Given Circle *4 in.* diam. Inscribe small circles as shown.

Use *Bow Pencil* on smaller circles.

NOTES

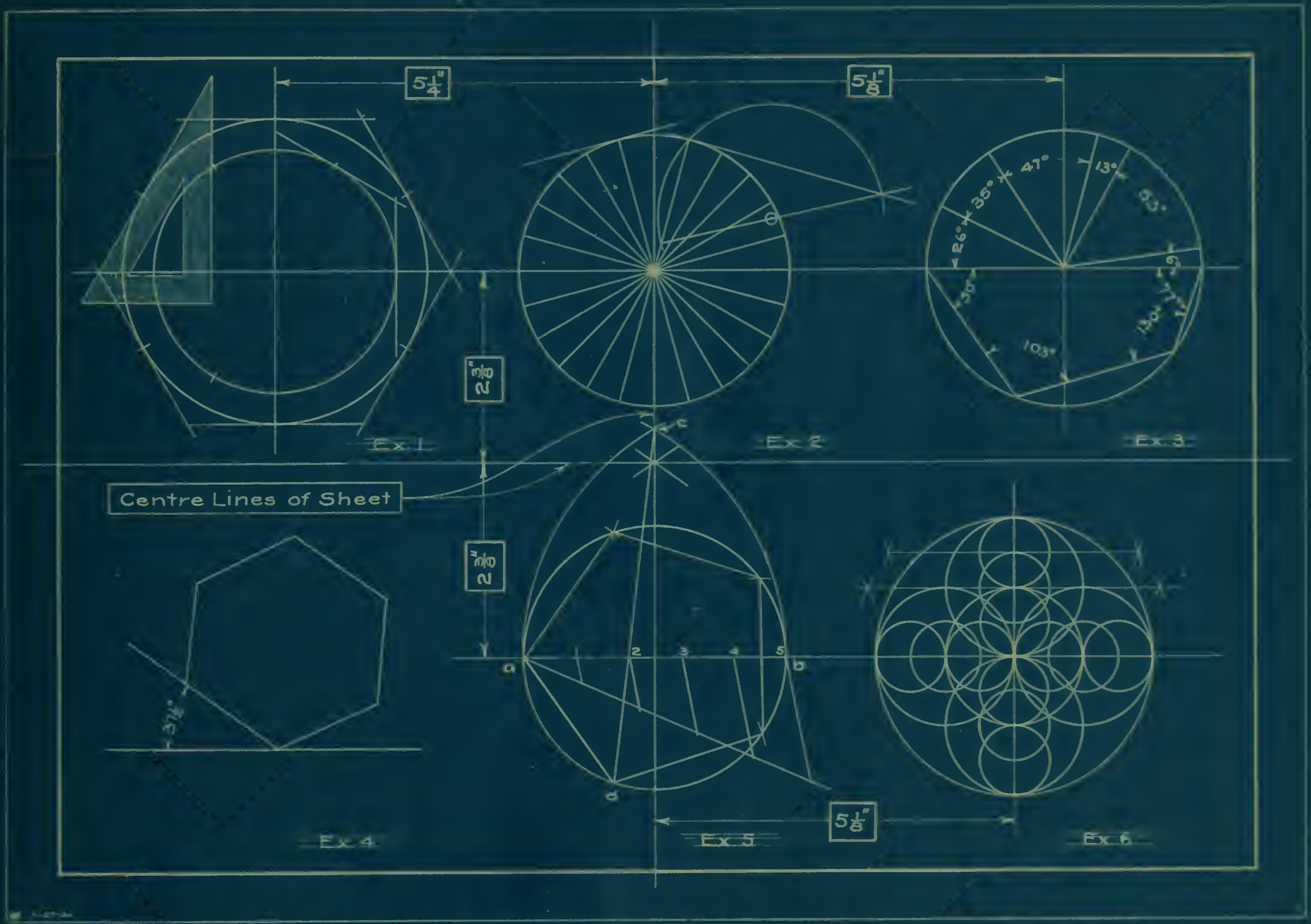
A. *Lines* and *Circles* to be:

(*a*) *Fine.*

(*b*) *Uniform.*

(*c*) *Accurately drawn.*

Use *6H* Pencil and *6H* lead in Compasses. (Sharpened. See Page 2–*A*–*c.*)



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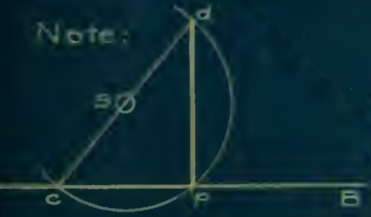


To erect a perpendicular to AB at p.
Draw circle thro' p, center s = any point.
Draw cd thro' s. pd = perpendicular.
(Angle cpd inscribed in semi-circle = 90°.)

Sheet 3

SHEET 4

Practice with Instruments (*continued*)

Inking

INKING

PENCILLING

I. Lines to be: (*a*) *FINE.*

(*b*) *UNIFORM.*

(*c*) *ACCURATE.*

LAY OUT SHEET AS SHOWN.

II. *Ex. 1.* Space lines $\frac{1}{4}$ *in.* apart.

III. *Ex. 2.* Space points $\frac{1}{4}$ *in.* horizontally and vertically. (Lines at 45°.)

IV. *Ex. 3.* Space lines $\frac{1}{4}$ *in.* apart.

First draw diagonal; then draw lines in order, **A**, **B**, **C**, **D**, etc.

V. *Ex. 4.* Space points $\frac{1}{2}$ *in.* apart.

VI. *Ex. 5.* **Spiral.**

(*a*) Make **ac** = $\frac{1}{4}$ *in.*; **ab** = $\frac{1}{8}$ *in.*

(*b*) With **a** as centre, draw all semicircles *above* horizontal line. With **b** as centre, all semicircles *below*.

Use **a** and **b** alternately to develop *Spiral*. Continue as far as possible without conflict.

VII. *Ex. 6.* Two *Upper* Circles, *2 in.* and *1 in.* diam. respectively. Two lower, *3 in.* and *2 in.* Centres, *2 in.* apart. Radii of tangent Arcs = *1 in.* and *2 in.* respectively.

VIII. *Ex. 7.* Space points $\frac{1}{4}$ in. apart on horizontal line. Complete figure as shown.

Use *Bow Pencil* for small circles.
Draw all curves of one radius at one time.

INKING

A. (*a*) Sheet is to be completed first in *pencil.*

(*b*) *Do not begin to ink until sheet has been submitted for approval, and has received endorsement of one of the instructors.*

B. (*a*) Do not fill pen too full (see PAGE *2–B*).

(*b*) Clean pen often.

C. (*a*) All lines to be **Black** and of **Medium Width**, *except* **Border**, which is to be **Heavy** and added *last.* (See note on blue print.)

(*b*) In inking, proceed in same manner as with pencil.

Begin at *Left* and work towards *Right*, and from *Top* work towards *Bottom*.

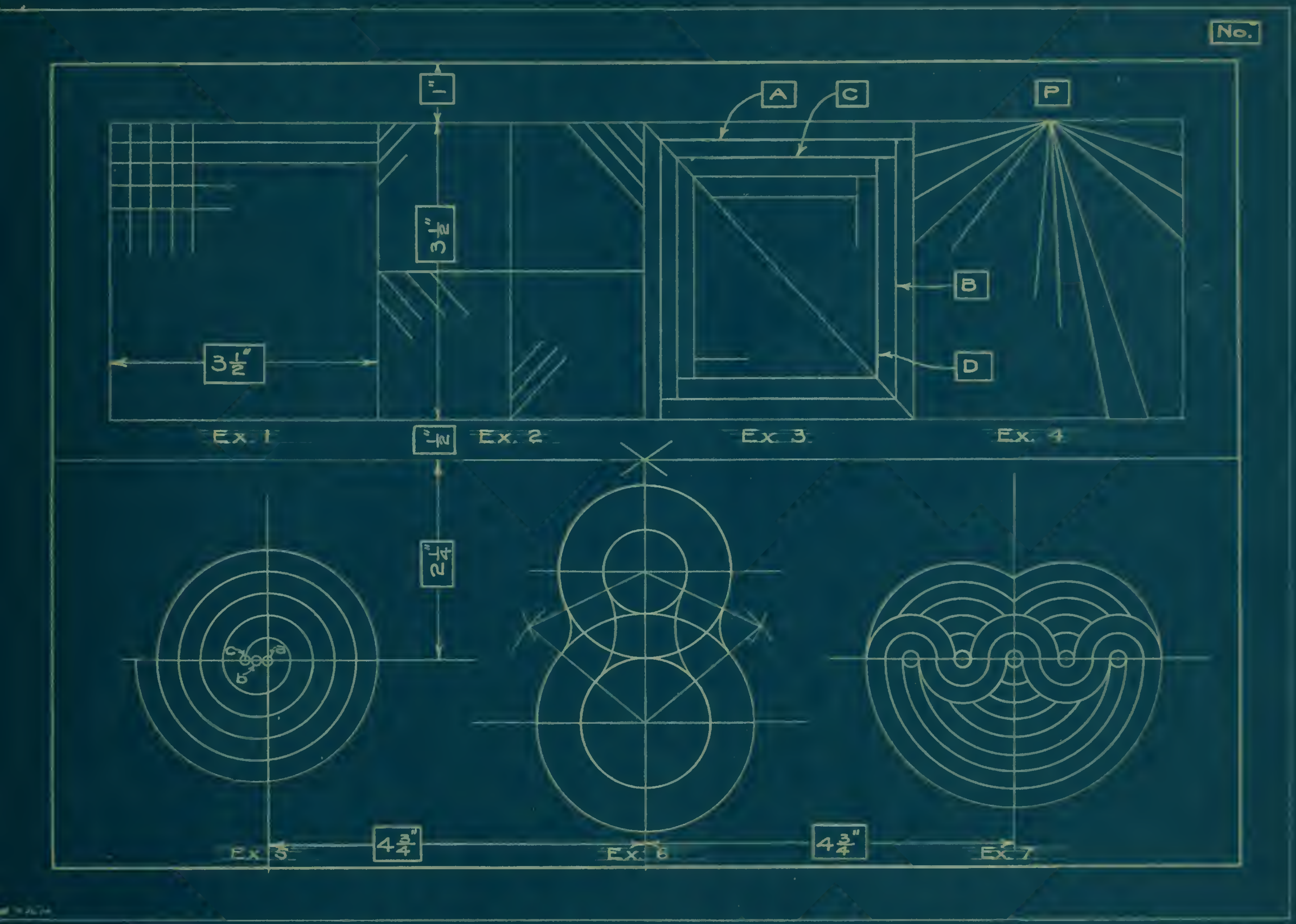
(*c*) In **Ex. 4** draw lines *to* point **P**, *not away* from it. Wait till each line dries before drawing the next.

This to avoid blotting.

(*d*) In *Ex. 5, 6, and 7*, omit construction and Centre Lines.

(*e*) In Lettering use drawing ink and writing pen.

(*f*) *Do not ink Cutting Line.*



Note: In inking make "Medium Lines" about thus:

"Heavy Lines" about thus:

Sheet 4

SHEET 5

Practice in Straight Lines and Arcs
Dimensioning and Crosshatching
Tracing

SHEET 5 – PRACTICE IN STRAIGHT LINES AND ARCS, ETC.

TRACING

DIRECTIONS

I. **Order of Pencilling.** (Sheet *B*–Page *18*.)

Stage 1. **Block out** all drawings on sheet. (**6 H** pencil.)

First *Centre Lines*, if any, then *Outlines*.

Stage 2. **Develop** drawings and **Strengthen** *Outlines*. (**2 H** pencil.)

(*Straight Lines* before *Curves*. See Sheet *B–3*.)

Stage 3. Add **Dimension Lines** (*very light*) and **Arrow Heads.** (**2 H** pencil.)

Stage 4. **Finish.**

- (*a*) *Dimension Figures.* (Sheet *B–4* and *5*.)
- (*b*) *Lettering.*
- (*c*) *Crosshatching.*
- (*d*) *Checking.*

II. **Order of Inking.** (Sheet *B–2*.)

Use *Rough Side* of Tracing Cloth.
Rub with *powdered chalk* before inking.

Stage 1. All the *main outlines* of all the drawings.

- (*a*) *First* all **Curves.***
- (*b*) *Then* all **Straight Lines.** (Black Medium.)

Stage 2. **Dimension Lines** (including "*Extension*" *Lines*) and **Centre Lines** (if any). (Red-Light.)

Stage 3. **Arrow Heads, Figures,** and **Lettering.** (Use *Writing Pen.*) (Black.)

Draw light guide lines on tracing cloth in pencil before lettering.

Stage 4. (*a*) **Crosshatching.** (Black-Light.)
(*b*) **Border.** (Black-Heavy.)

NOTES

A. (*a*) In both Pencilling and Inking it is best to carry out each Stage for the *whole* sheet before beginning the next Stage.

(*b*) **The Pencil sheet is to be approved before Tracing is begun.**

B. **Dimensions.**

(*a*) For dimensions in *Quarters*, *Eighths*, *Sixteenths*, etc., use "**Architect's**" Scale.
For dimensions in Decimals use "**Engineer's**" Scale.

(*b*) Avoid taking dimensions with Compasses directly from Scale.

This scratches scale and ruins compass points. Lay off distance on paper at required point and set compasses to this distance.

(*c*) *Small Circles* are placed around centres of arcs to assist in finding them when tracing.

These circles can be omitted in inking and short *cross lines* substituted.

C. **Crosshatching.**§

(*a*) *Crosshatching* is used to indicate a "**Cross Section**" of an object drawn.

(*b*) It is usually drawn with the **45°** *Triangle.*

Other angles may, however, be used.

(*c*) *Space lines about $\frac{1}{16}$ in. apart by EYE ALONE.*

(*d*) Do not cross Figures or Arrows with hatching lines.
(*To avoid this the Crosshatching is usually added last.*)

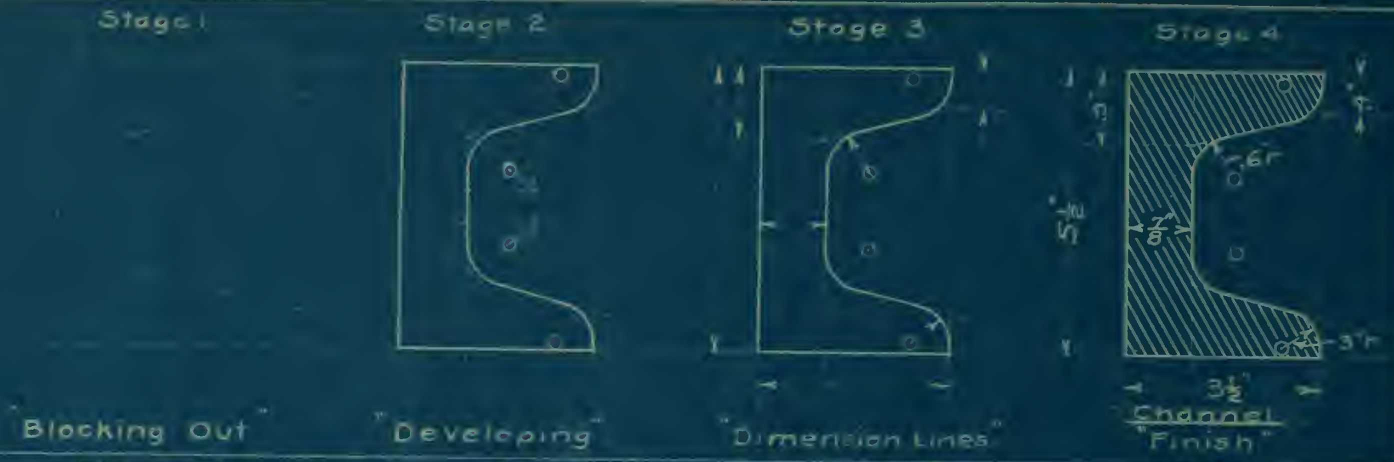
---

* This procedure gives best results in *joining Curves* and *Straight Lines* smoothly.
The short curves shown on this sheet are often called "**Fillets.**"

§ When a drawing is to be traced the Crosshatching is often omitted in pencil, or is indicated very briefly by Free Hand lines.

①

ORDER OF PENCILLING
4 Stages



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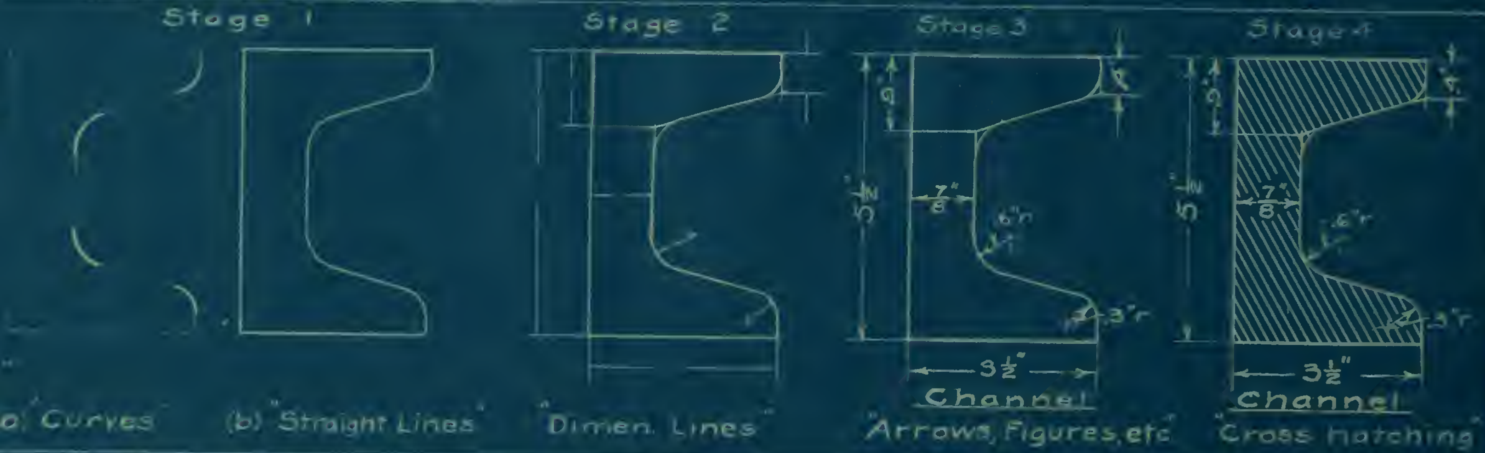
ORDER OF INKING
4 Stages



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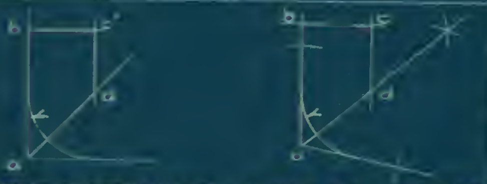


TO CONNECT 2 STRAIGHT LINES BY AN ARC

(1) Bisect angle

(2) Draw cd parallel to ab – (making bc equal to given radius)

(3) d equals centre for arc.

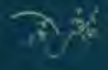
④

DIMENSIONS

(a) 3'=3 feet · 3"=3 inches

(b) Small dimensions thus: $\rightarrow\frac{1}{4}''\leftarrow$ or $\rightarrow|\leftarrow\frac{1}{16}''$

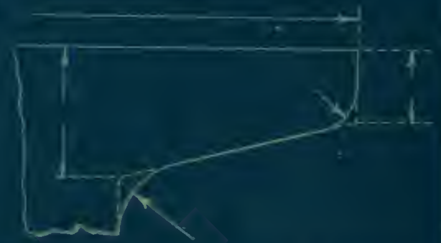
(c) Small radii thus:



(d) "Extension Lines" are used when dimensions come outside the drawing – see ⑤

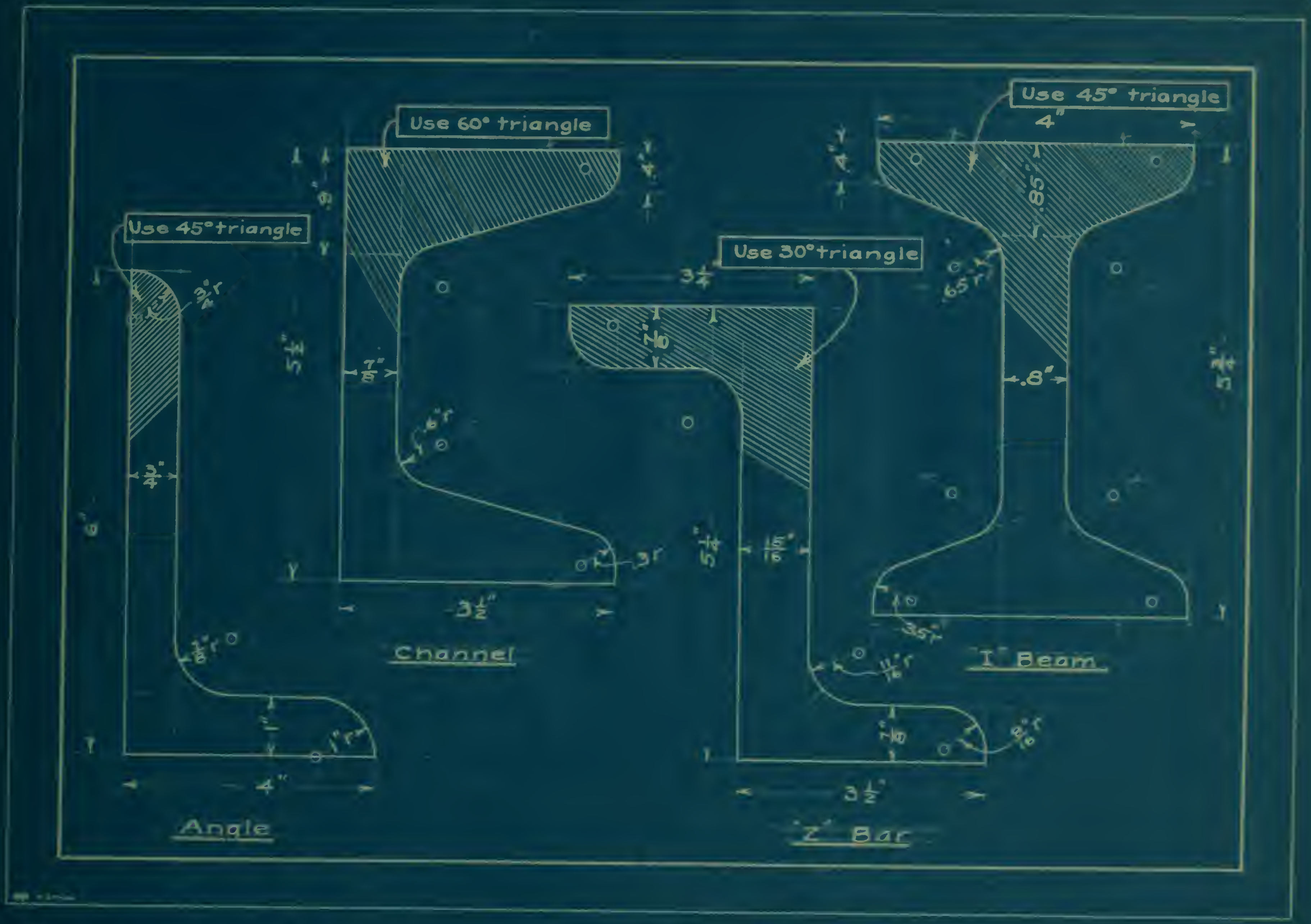
⑤

DIMENSIONS



Extension Lines here shown dotted and are often so drawn. In this course they are to be full

Sheet B



Note In Inking (a) Omit all construction lines

(b) Light Lines about thus

(c) Medium Lines about thus

(a) Heavy Lines about thus

Sheet 5

SHEET 6

Conic Sections

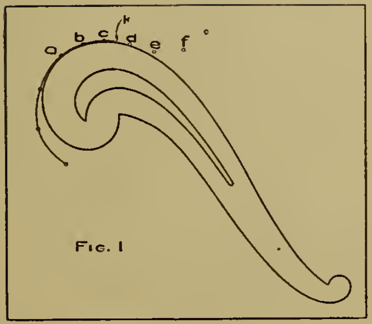


Fig. I

Use of French Curve or Scroll

Given a series of points to be joined by a *smooth curve.*

Find portion of Scroll to fit at least **3** points (as **b**, **c**, **d**). Then draw from **b** to **k** (about half way between **c** and **d**). Change Scroll to fit **c d e**, and draw curve from **k** to half way between **d** and **e**. Continue thus.

Sometimes the Scroll will fit more than three points, but in any case stop half way between last two, as suggested above.

DIRECTIONS

I. (*a*) Follow the *Order of Pencilling* given on Page *17*, beginning with the necessary construction lines.

(*b*) *Strengthen* only the *Outlines* of *Curves*. (Use "**French Curve**" or "**Scroll**" — see Page *20*.)

(*c*) *Ink in* (on Duplex Sheet) only the *Curve outlines* (Black-Medium) and *Border* (Black-Heavy).

(*d*) *Small Circles* about *Reference Points* can be inked in *Black*. (Use *Bow Pen*.)

II. PROBLEM 1. **Ellipse** (*Exact Method*).

(*a*) Lay off line, as a^1b^1, equal to *Major Axis*. Use this for measuring Radii (as a^1e^1 and b^1e^1) in developing curve.

(*b*) Find at least **5** *Points* for each quadrant.

(*c*) Add explanatory equation for one point of curve, as indicated.

III. PROBLEM 2. **Ellipse** (*Approximate Method*).

When the *Major* and *Minor Axes* do not differ much in length, a simple approximate method, by means of circular arcs, can be used to replace the more complicated exact method.

Construction as shown.

IV. PROBLEM 3. **Parabola**.

Divide **ab** and **ac** each into at least **8** parts.

V. PROBLEM 4. **Hyperbola**.

(*a*) Draw the large rectangle by dimensions given.

(*b*) Begin the curve at **a**.

Find enough points to give a smooth curve.

(*c*) The divisions on **ab** *need not be* of *uniform* length.

NOTES

A. **Ellipse — Parabola — Hyperbola.**

These curves belong to the family of **Conic Sections**, so called because they are derived by the intersection of planes with the surface of a **Cone**.

Their exact derivation will be taken up in *Sheet 12*. This sheet deals merely with certain geometrical methods of drawing them.

B. PROBLEM 1.

The **Ellipse** can be defined as *the path traced by a point*, *the sum of whose distances from two fixed points always remains constant*.

(*a*) The two fixed points are called "**Foci**" (singular, "**Focus**").

(*b*) The long diameter or *Length* of Ellipse is called the "**Major Axis.**"

The short diameter or *Width* is called "**Minor Axis.**"

(*c*) Study above definition and Problem *1*. It will be seen that the sum of the distances from the *Foci* to the moving point will always equal the *Major Axis*. Then, with Major and Minor Axes given, the Foci can be found by drawing arc with Radius $\mathbf{R} = \frac{1}{2}$ *Major Axis*, and one end of Minor Axis as centre (see diagram).

The method of developing the Ellipse is indicated, and, as it follows the definition given above, it is called the "**Exact Method.**"

C. PROBLEM 3. **Parabola.**

(*a*) The exact definition of this curve is left for *Analytical Geometry*.

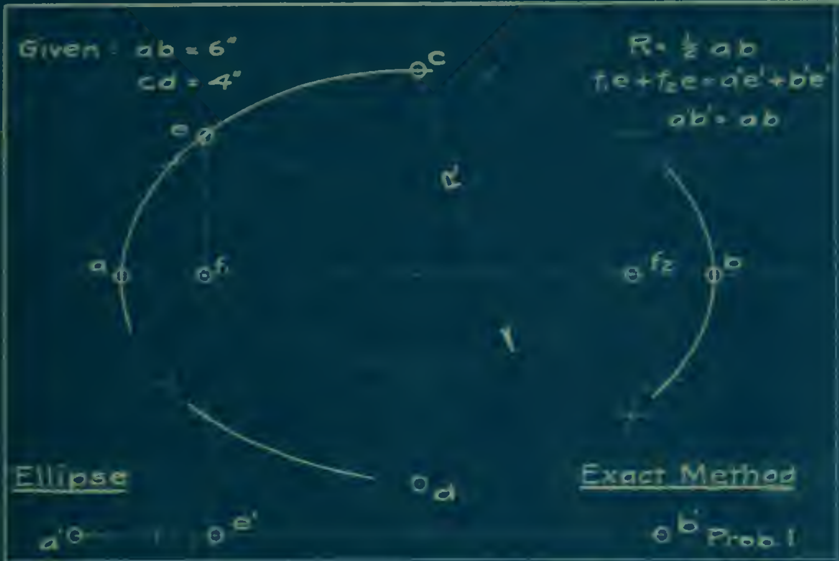
(*b*) When the width and height of the curve are given it can be drawn as indicated.

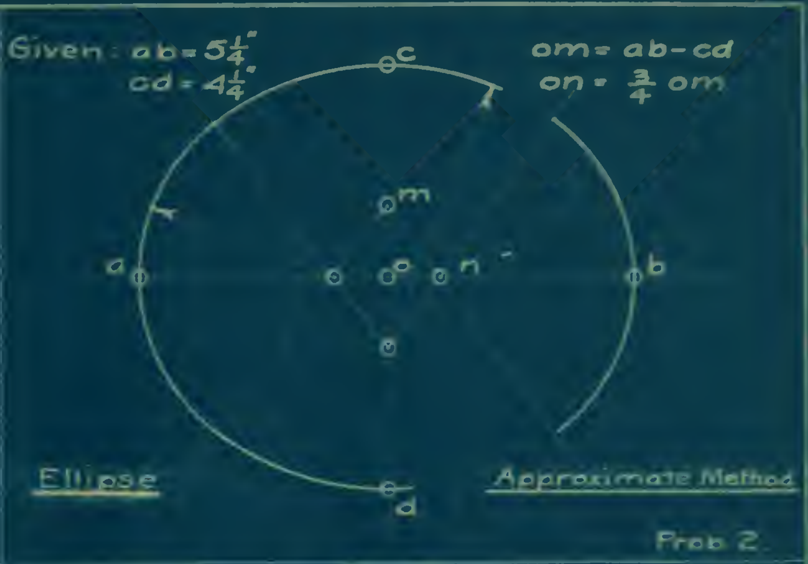
D. PROBLEM 4. **Hyperbola.**

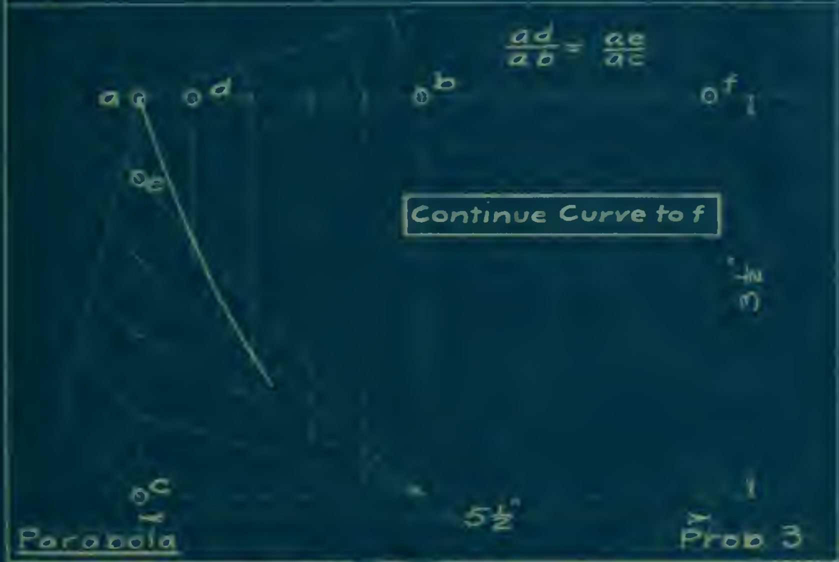
(*a*) As in the case of the *Parabola*, the exact definition is here omitted.

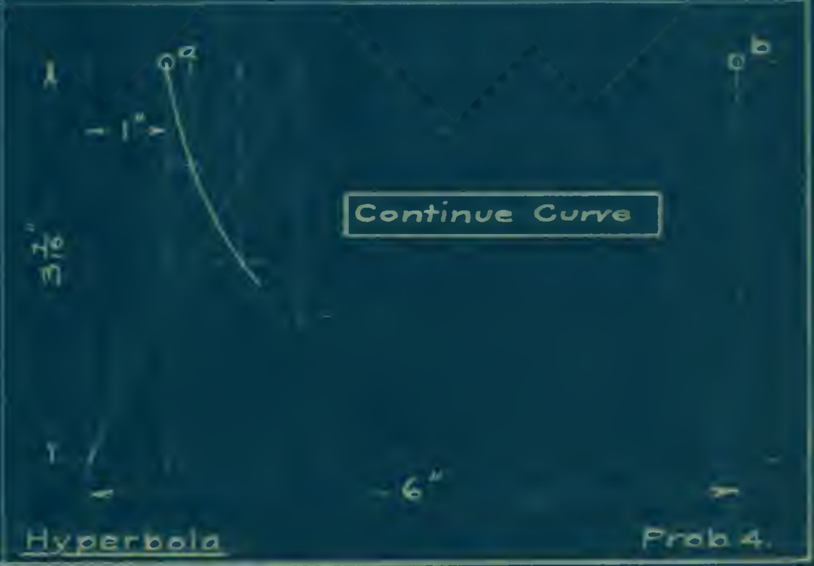
(*b*) Only one-half the Curve is drawn by this construction — the remaining half would be *similar* but *inverted*, continuing from point **a**.

(*c*) This construction is much used in the representation of the *Theoretical Indicator Card* of a *Steam Engine*.


Given: ab = 6"
cd = 4"
R = ½ ab
f₁e + f₂e = a'e' + b'e'
a'b' = ab
c
e
R
a
f₁
f₂
b
d
Ellipse
Exact Method
a'
e'
b'
Prob. 1


Given: ab = 5¼"
cd = 4¼"
om = ab − cd
on = ¾ om
c
m
a
o
n
b
d
Ellipse
Approximate Method
Prob. 2


ad/ab = ae/ac
a
d
b
f
e
Continue Curve to f
3½"
c
5½"
Parabola
Prob. 3


a
b
1"
Continue Curve
3½"
6"
Hyperbola
Prob. 4.

Sheet 6

SHEET 7

Cycloids

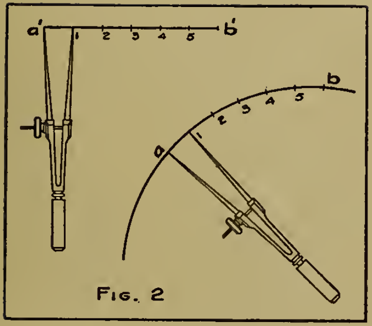


Fig. 2

To Rectify a given Arc

Given arc **ab** (Fig. *2*). Use Bow Spring Dividers. Step off *short distances* along arc **ab** and same number along Straight Line.

This makes **a'b'** equal, approximately, are **ab**.

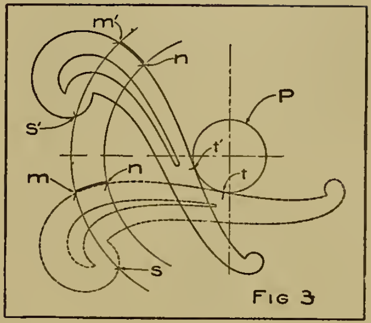


Fig 3

To Transfer a Gear Tooth Curve

Place *Scroll* to coincide with given curve (**mn**) (Fig. *3*). Mark point **n** on Scroll and draw *Circle* **P** tangent to Scroll at any convenient point (as **t**). Change Scroll to new position and draw **m'n'** as shown.

Alternative Method

Omit *Circle* **P** and use mark (as **s**) to locate curve.

SHEET 7 — CYCLOIDS

DIRECTIONS

I. Begin construction by laying out *Centre Lines* of circles. Draw all construction circles *very light.*

II. PROBLEM 1.

(*a*) Make *Rolling Circle* (**R. C.**) = **2″** diam.

(*b*) Use **8**, **10** or **12** points on **R. C.**

(*c*) In stepping off distances on circles use *small Dividers.* (See Page *23*–Fig. *2.*)

When the curve comes back to the straight line, how far will it be from the initial point "**O**"? *Answer by giving proper dimension line and figures.*

III. PROBLEM 2.

(*a*) Take points about **15°** apart.

(*b*) Continue curve as far as possible without conflict.

IV. PROBLEM 3.

(*a*) Make **R. C.** = **2″** diam. for both curves.

(*b*) Use **10** or **12** points on **R. C.** for *Epicycloid.*

(*c*) " **8** " **10** " " *Hypocycloid.*

(*d*) Continue curved as far as possible with conflict.

V. Strengthen outlines of *Curves* and *Gear Teeth* only. (See Page *23*–Fig. *3.*)

VI. Ink in :—

(*a*) *Curves* and *Gear Teeth.*	(Black-Medium.)
(*b*) Small *Reference Circles.*	(Black.)
(*c*) *Border line.*	(Black-Heavy.)

NOTES

A. **Cycloid, Involute, Epicycloid, Hypocycloid.*** These curves belong to the family of **Cycloids.** They may all be defined as *the path traced by a Point on the Circumference of a Circle which rolls on a given Line* (either Straight or Curved).

B. PROBLEM 1. **Cycloid.**

R. C. rolls on a *Straight Line.*

(*a*) Take points on initial position of **R. C.**

(*b*) Find successive positions of **R. C.** by making distance **O–1** on **AB** = **arc O–1** on **R. C.**, etc. (See Page *23*–Fig. *2.*)

(*c*) Locate the successive positions of **O** by stepping off the proper arcs in the direction of the arrows.

The length of these arcs will, in each case, be the distance over which the circle has rolled. To verify this, try a coin rolling along the edge of the **T**-square.

C. PROBLEM 2. **Involute.**

A special case of the *Epicycloid.*

Straight Line (Circle of Infinite Radius) rolls on a *given Circle.*

More simply, by a point at the end of a String which, being held taut, is unwound from a given circle.

The String is taken in successive positions by drawing tangents at end of successive radii, and the proper distances are stepped off as shown.

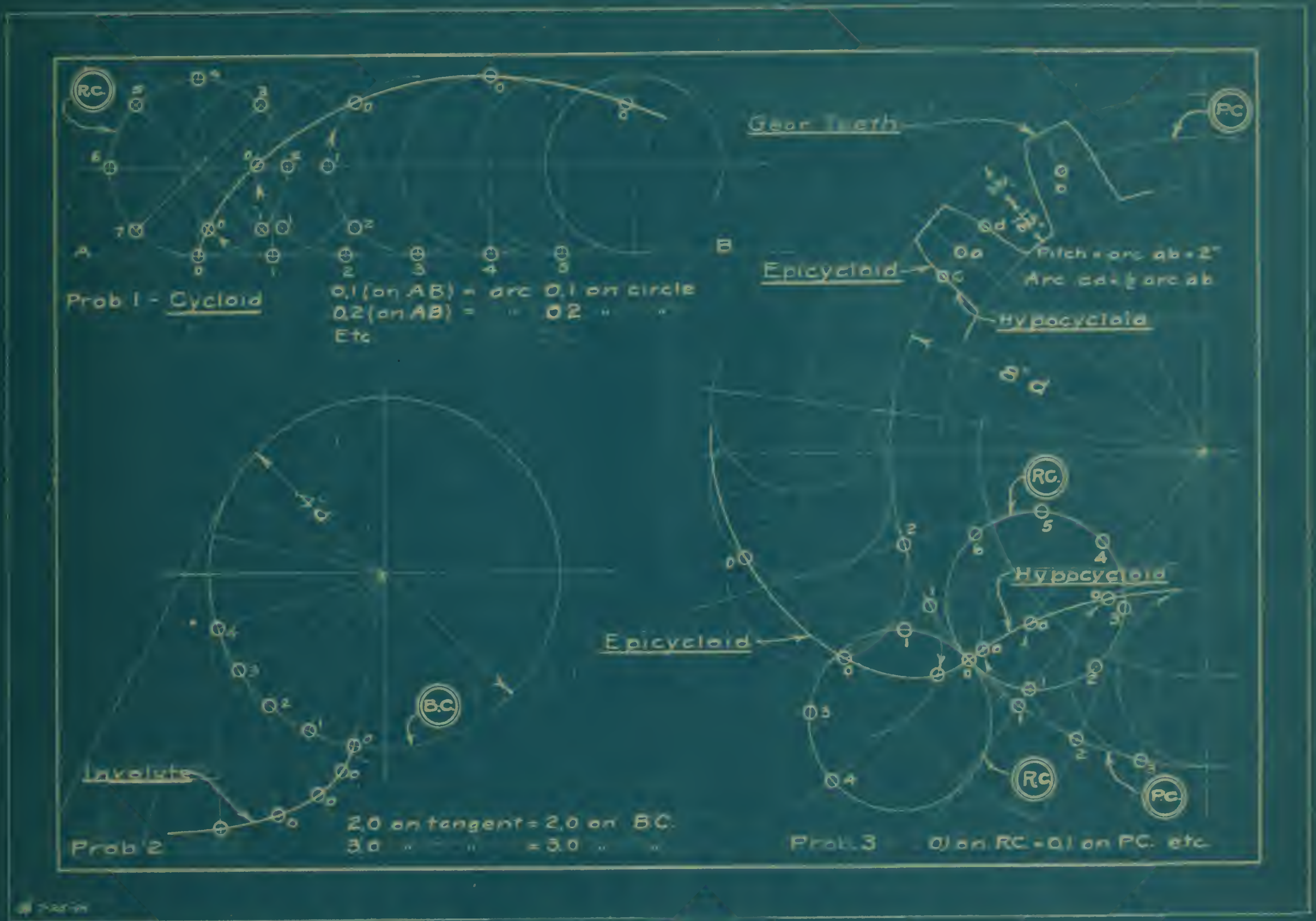
D. PROBLEM 3. **Epicycloid and Hypocycloid.**

Former = **R. C. outside** of another *Circle.*
Latter = " **inside** " "

(*a*) Construction similar to Prob. 1.

(*b*) **Gear Teeth** are formed by *Epicycloids* and *Hypocycloids* drawn, respectively, *outside* and *inside* a circle known as "**Pitch Circle.**" The "**Pitch**" of the teeth is the distance between the centres of successive teeth, measured along the *Pitch Circle* (arc **ab** in diagram).

* Cycloid — *κύκλος* = "*Circle.*"
Epicycloid — *ἐπί* = "*upon*" + *κύκλος.*
Hypocycloid — *ὑπό* = "*under*" + *κύκλος.*
Involute — (Latin) **in** = "*upon*" + **volvo** = "*to roll.*"



Note: PC = Pitch Circle BC = Base Circle RC = Rolling Circle.

4"d means 4 inches diameter.

Sheet 7

SHEET C

Orthographic Projections

Illustration Sheet

SHEET C — ORTHOGRAPHIC PROJECTIONS

THIS SHEET IS FOR ILLUSTRATION ONLY

I. The technical development of **Projections, Projection Planes**, etc., is left for later consideration.
(See Sheet *M*, Page *86*.)

II. **Orthographic Projection**, described simply, is a method of delineating an object accurately and adequately by means of one or more views, so grouped as to be easily read together, and thus give a clear idea of the appearance, form, and dimensions of the object.

III. EXAMPLE: **Student Lamp.**

(*a*) Let **F. V.** = *Front View*. **R. V.** = *Right Side View*.
T. V. = *Top View*. **L. V.** = *Left Side View*.

(*b*) If we take a *Student Lamp*, place it on a table and stand far enough away so that the rays from all points of the lamp to the eye are practically *parallel*, we can reproduce on paper, to a convenient scale, the corresponding appearance of the lamp.

Place this so-called **View** at the bottom and centre of a sheet of paper and label it **F. V.** (see Sheet **C**).

Now look at lamp similarly from **above** and place *View* so produced *above* **F. V.**, labelling it **T. V.**

Then look at lamp from **Right Side**, and place corresponding *View* to the *Right* of **F. V.** Call it **R. V.**

Similarly place **L. V.** (looking at Lamp from **Left**) as shown.

(*c*) Label *Centre Lines* of **Tank, Standard,** and **Shade** as shown.

Add Symbols "**R**" and "**L**" (*Right* and *Left*).

Add *Reference Points* and *Dimensions* as shown.

IV. Then **Note Carefully**: —

(*a*) Point **1** of **T. V.** lies *vertically above* Point **1** of **F. V.**

(*b*) Point **1** lies on *same horizontal line* in **F. V.** and **T. V.**

(*c*) (Looking at **T. V.** from direction "**N**" and comparing with **R. V.**) — Point **1** lies at distance (**C**) to "**R**" of *C. L. Standard* * in both Views.

(*d*) (Similarly comparing **T. V.** from direction "**M**" with **L. V.**) — Point **1** lies at distance (**C**) to "**L**" of *C. L. Standard* in both Views.

(*e*) By means of the above analysis, with *two Views* of an object given, we can usually locate the position of corresponding points in a *third* or *fourth View*, and thus complete these views.

If necessary we could develop a *Bottom View* which would then be placed *below* the **F. V.**

V. (*a*) Any view of an object may be taken as a **F. V.**, but having selected and located this, the other Views must be grouped about it in accordance with the above principles (**T. V.** always at **Top** — **R. V.** always at **Right**, etc.).

(*b*) In general, *three Views* are enough to clearly describe an object (as will be seen in example above), but where necessary *four* or even *five* Views may be taken.

(*c*) *Hidden Lines* are represented dotted, as shown.

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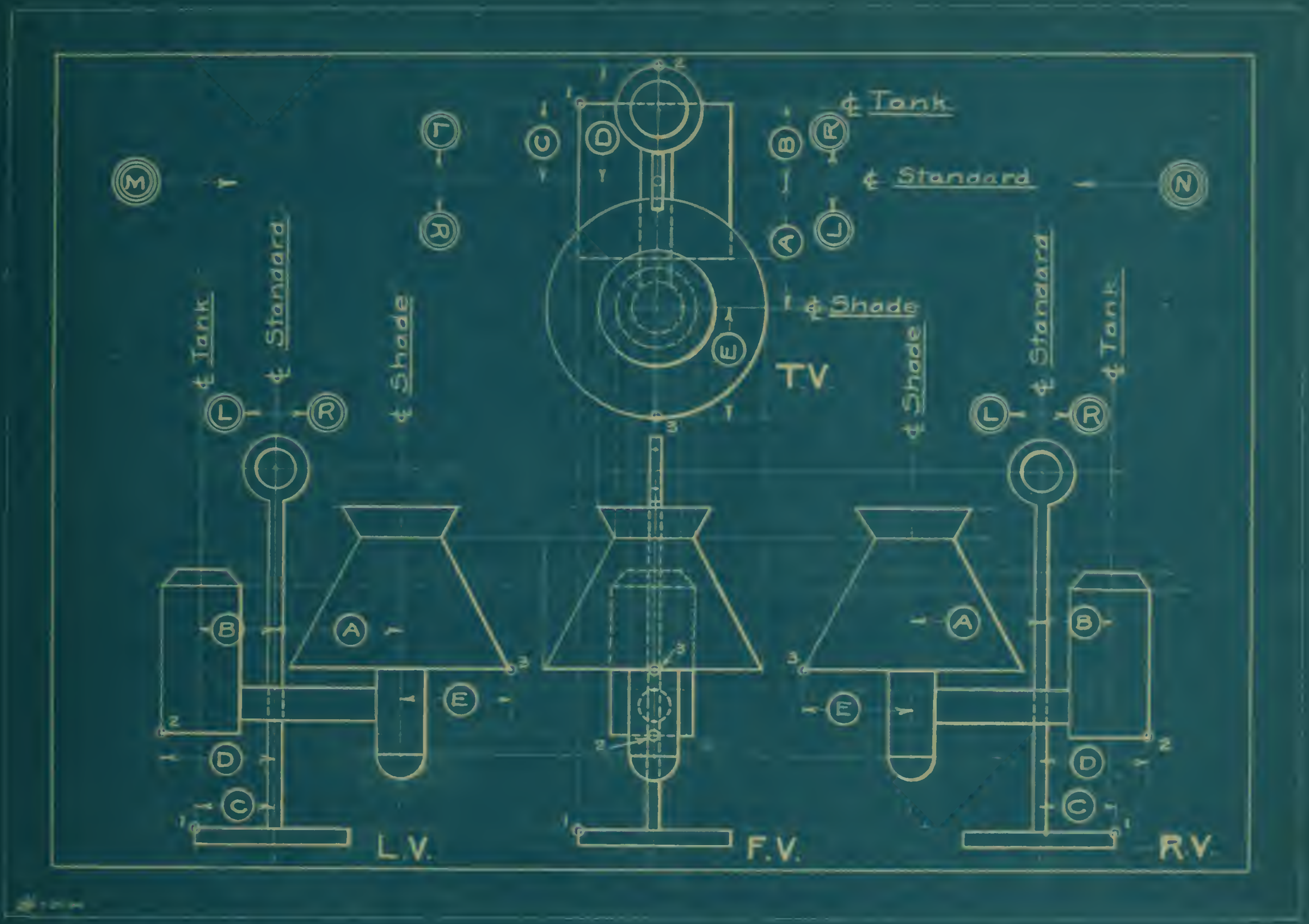
* *C. L.* stands for *Centre Line.*



Note: The symbol "℄" stands for "CENTRE LINE"

Sheet C.

SHEET 8

Orthographic Projections

Problems

SHEET 8 – ORTHOGRAPHIC PROJECTIONS

PROBLEMS

DIRECTIONS

I. Study carefully Sheet **C**. (PAGES *27* and *28*.)
Apply principles there shown to development of following problems.

II. PROBLEM 1.
- (*a*) Lay out *Centre Lines.*
- (*b*) Draw *light* circles (diams. as given in **T. V.**).
- (*c*) Block out Hexagons (use 60° Triangle).
- (*d*) Block out **F. V.** and **R. V.**

III. PROBLEM 2.
- (*a*) Lay out centre lines.
- (*b*) BLOCK OUT ALL THREE VIEWS TOGETHER.
  (Draw Pentagon by method. PAGE 81–*8*.)

IV. PROBLEM 3.
- (*a*) Proceed as in PROB. 2.

V. PROBLEM 4.
- (*a*) Same procedure.
- (*b*) The subject is the same as PROB. 3, turned through an angle of 30°.

NOTE: **We still use Horizontal and Vertical centre lines.**

VI. Add, in each problem, at least *3 selected Reference Points* (other than those given on the blue print) in **all views.**

VII. OMIT ALL DIMENSION LINES AND FIGURES ON THIS SHEET.

VIII. Ink in *only*: —
- (*a*) All centre lines (*Red-light*).
- (*b*) Circles about reference points (*Black*).
- (*c*) Circles about "**R**" and "**L**" (*Black*).
- (*d*) Border line (*Black-heavy*).

NOTES

A. Follow the **Order of Pencilling** given on PAGE 17.
- (*a*) It is usually wisest to block out the entire sheet before beginning to strengthen any outlines.*
- (*b*) *Develop all views of an object together.*†
  Do not complete one view before beginning another.
- (*c*) In "Strengthening" HIDDEN LINES are *dotted.*

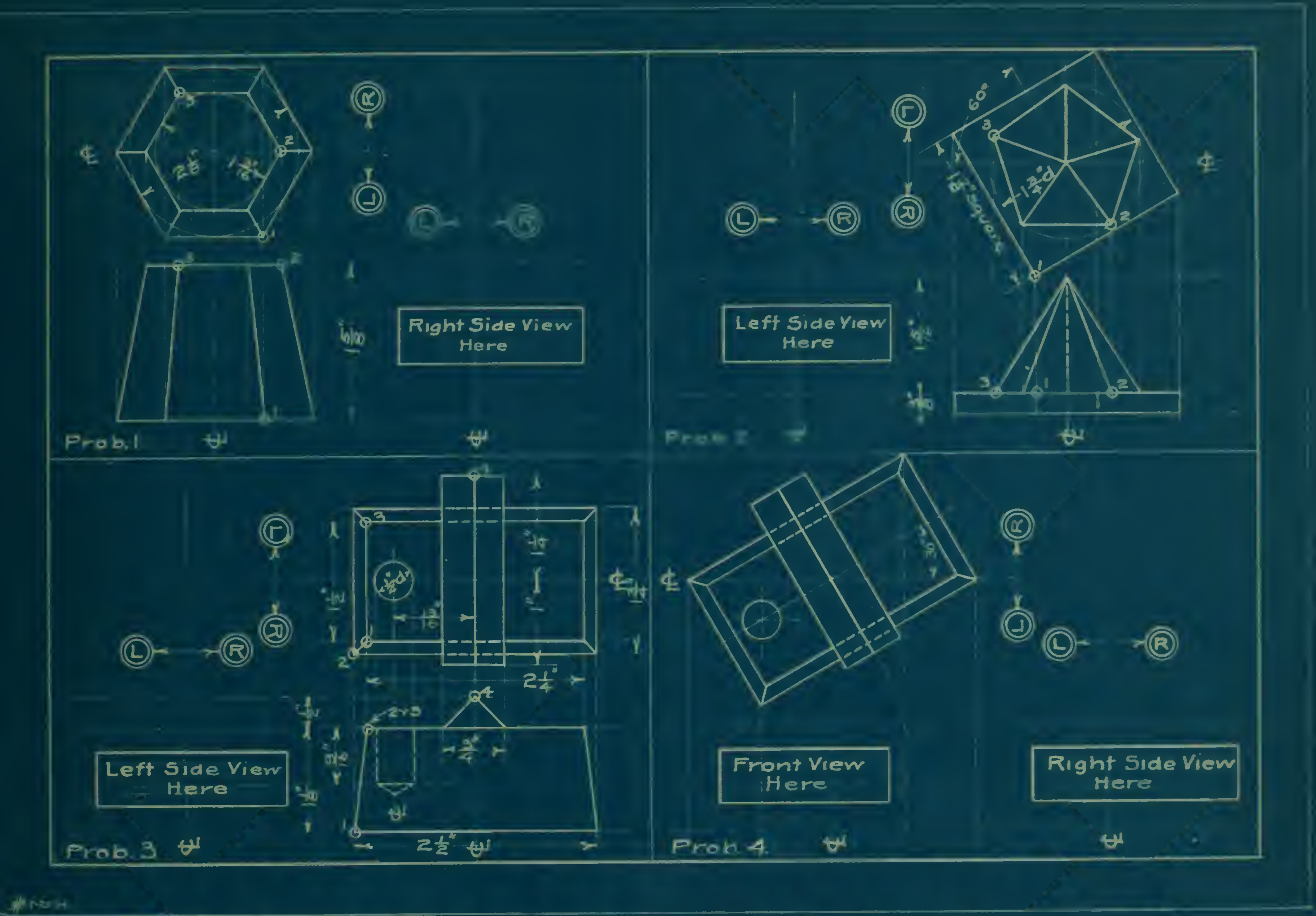
(When Blocking out draw hidden lines light and full: a light "*d*" placed on them will indicate that they are to be dotted later.)

B. PROBLEM 3.
- (*a*) The drawing represents a **Block** with a **Round Hole** in it, and a **Triangular Prism** on top.
- (*b*) The bottom lines of the hole can be drawn with the 30° Triangle.

---

* This method assists, particularly later on, in gauging the best arrangement of the drawings on a sheet, and prevents unnecessary erasure in correcting the arrangement.

† This will be found to economize time and to assist in understanding the relation of the various views. Where a horizontal line is to appear in **F. V.** and **R. V.** or **L. V.** draw it, at one stroke, through both views.
Similarly for vertical lines in **F. V.** and **T. V.**



Note: (a) Be careful to note whether or not corresponding reference points are correctly located and numbered in above print. If any correction is necessary, make it in red ink on the blue print.

(b) Make dotted lines about thus: — — — — — — — — 1/8" 1/16"

Sheet 6

SHEET 9

Orthographic Projections *(continued)*

Problems

PROBLEMS

DIRECTIONS

I. Proceed as in Sheet **8**.

(*a*) Lay out *Centre Lines.*

(*b*) Block out all 4 Views together. **(Stage 1.)**

(*c*) Develop drawing and Strengthen Outlines of all 4 Views. **(Stage 2.)**

(*d*) Add Dimension Lines and Arrows. **(Stage 3.)**

(*e*) Add Figures and Lettering. **(Stage 4.)**

II. Add at least 3 *selected Reference Points* (other than those given on blue print) in all views, and *Reference Dimensions* **A** and **B.**

III. Ink in, as hitherto: —

(*a*) Centre lines. (*Red-light.*)

(*b*) Circles about Reference Points and Letters.* (*Black.*)

(*c*) Border line. (*Black-heavy.*)

NOTES

A. (*a*) Use edge of Scale marked "$\frac{1}{4}$." This gives graduations corresponding to $\frac{1}{4}$ *inch* = 1 *foot*, which is the Scale called for in the drawing.

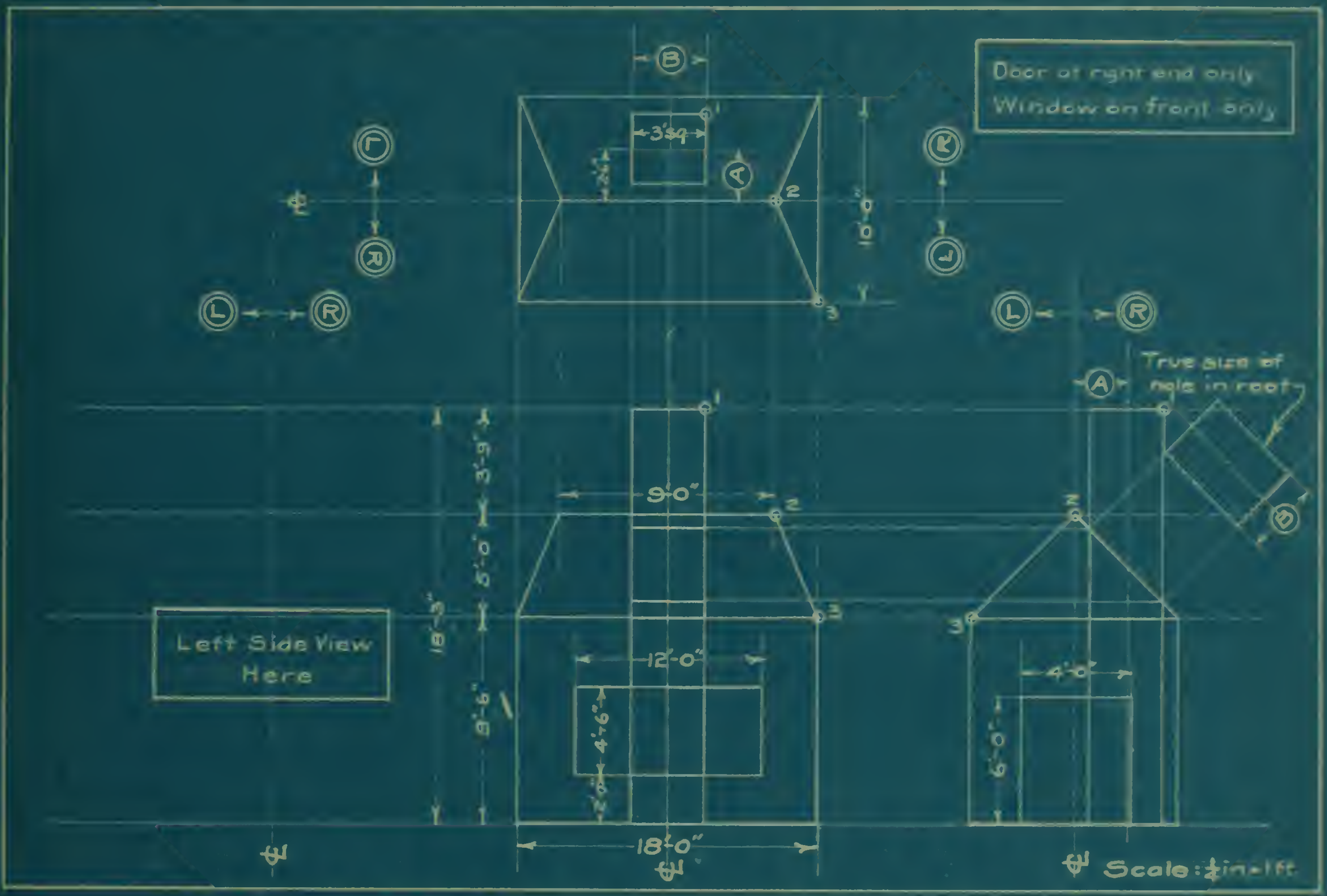
(*b*) **18′–3″** means **18** *feet*, **3** *inches*, etc.

B. In the blue print all lines have been drawn *full.* Remember that Hidden Lines are *dotted.*

In Strengthening, therefore, correct the lines of the blue print wherever necessary.

C. *Door* and *Window* are to be considered *Open.*

* "**A**," "**B**," "**L**," "**R**," etc., are "*Reference Letters.*"



Door at right end only
Window on front only

Left Side View Here

Scale: ¼ in = 1 ft

SHEET 10

Orthographic Projections (*continued*)

Problems

PROBLEM

DIRECTIONS

I. Follow directions for Sheet **9**.

II. Substitute for "?" the proper dimension figures taken from Sheet 9.

Note that the location of some dimensions has been changed, as a line should **only be dimensioned where it appears in its true length**.

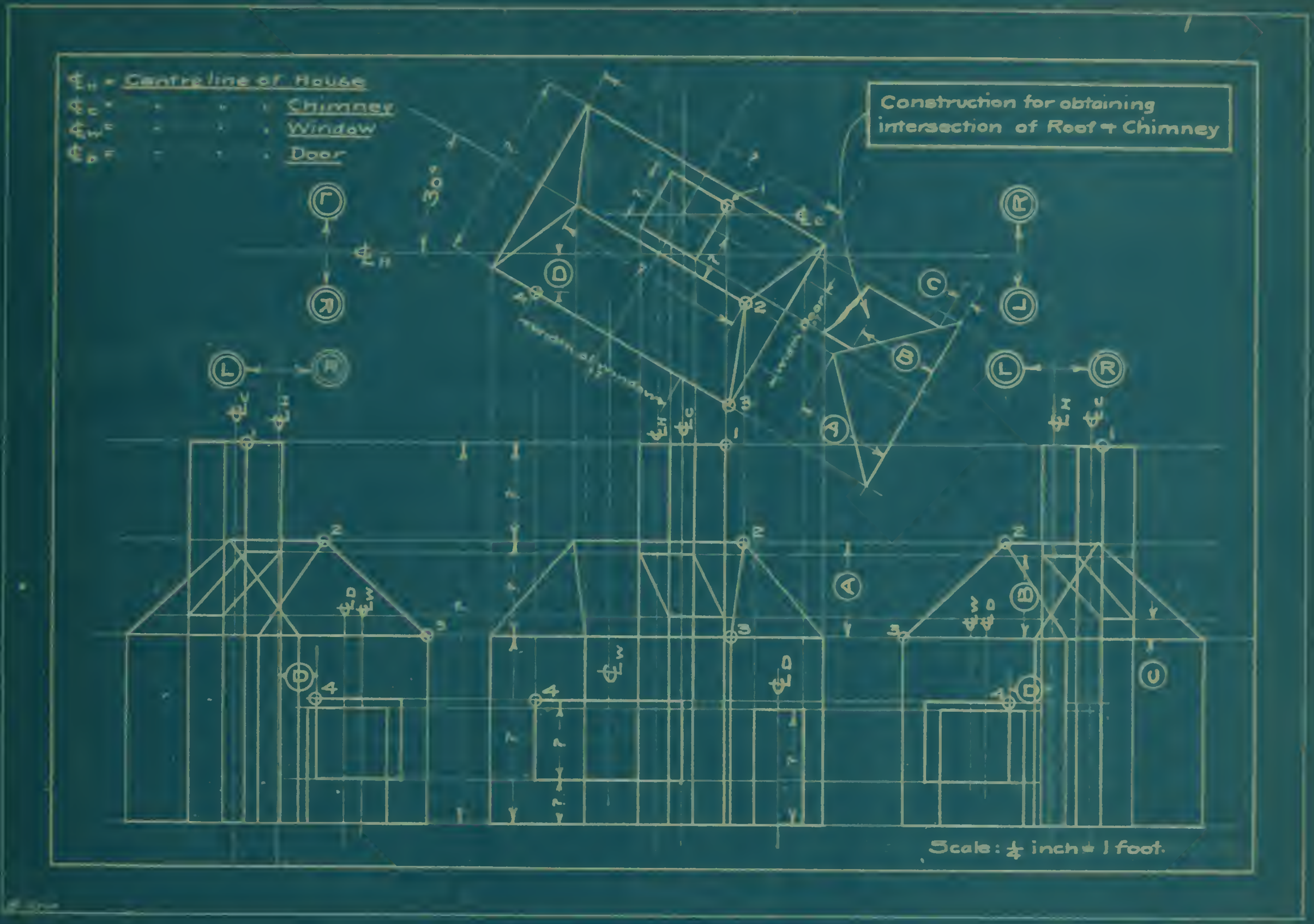
III. Add at least 3 selected Reference Points, and Reference Letters ("**A**," "**B**," etc.), as hitherto.

IV. Inking. Same as hitherto.

NOTES

A. This sheet shows the subject of Sheet 9 turned through an angle of 30°.

B. Remember, as before, that *Hidden Lines* are *dotted*.



Note: Be careful to note whether or not corresponding reference points are correctly located and numbered in above print. If any correction is necessary, make it in red ink on the blue print.

Sheet 10

SHEET 11

Development

DIRECTIONS

I. PROBLEM 1. **Truncated Prism.**

(*a*) Work out *Front*, *Top*, and *Side Views* of subject.

(*b*) Obtain *True Size* of top, as shown.

(*c*) **Develop** or *unfold* the resulting surface, as indicated.

II. PROBLEM 2. **Truncated Pyramid.**

Method same as for Problem 1.

III. For both problems.

(*a*) *Order of Pencilling* same as before.

(*b*) Add all *Reference Points* given on blue print in *all Views* and *in Development.*

(*c*) Add *Reference Dimensions.*

(*d*) Inking same as hitherto.

IV. Reproduce both *Developments* on piece of *Duplex Paper*. Cut out and fold to produce original objects.

NOTES

A. From now on, with the exception of Sheet *17* (Isometric Projection), all the problems and sheets of the course are based on the principles of *Orthographic Projection.* This term will, therefore, be omitted from the heading of the following sheets, and the title only of the special problem on each sheet will be given.

B. Given an object, like an irregular Box, to find the *size* and *shape* of a *sheet of material* which, when folded, will produce the object.

The solution of this problem is indicated on this sheet. The technical term by which this process is known is: —

Development of a Surface.

C. PROBLEM 2.

The Front View does not show the slanting edges of the Pyramid in their *true length.*

To find the true lengths, for development, use construction indicated.

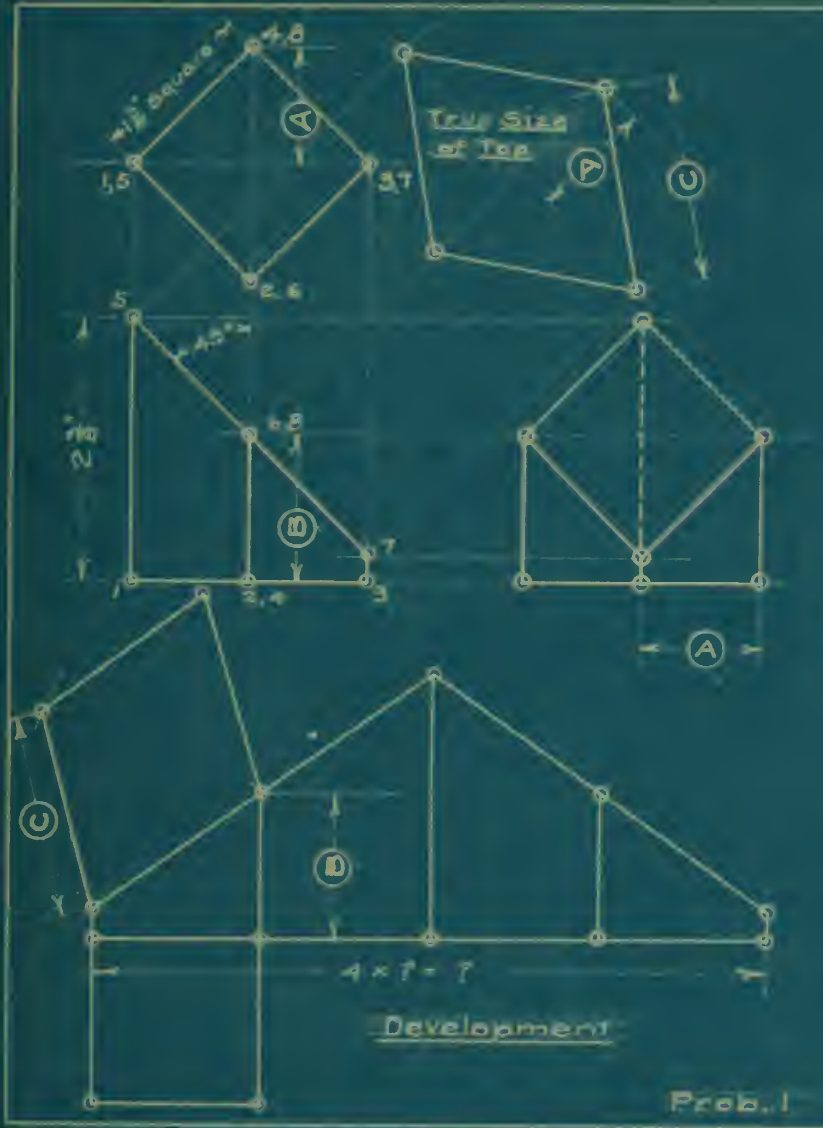
This corresponds to the following principle (*see note on blue print*): —

Let **ab** = **F. V.** of given Line.

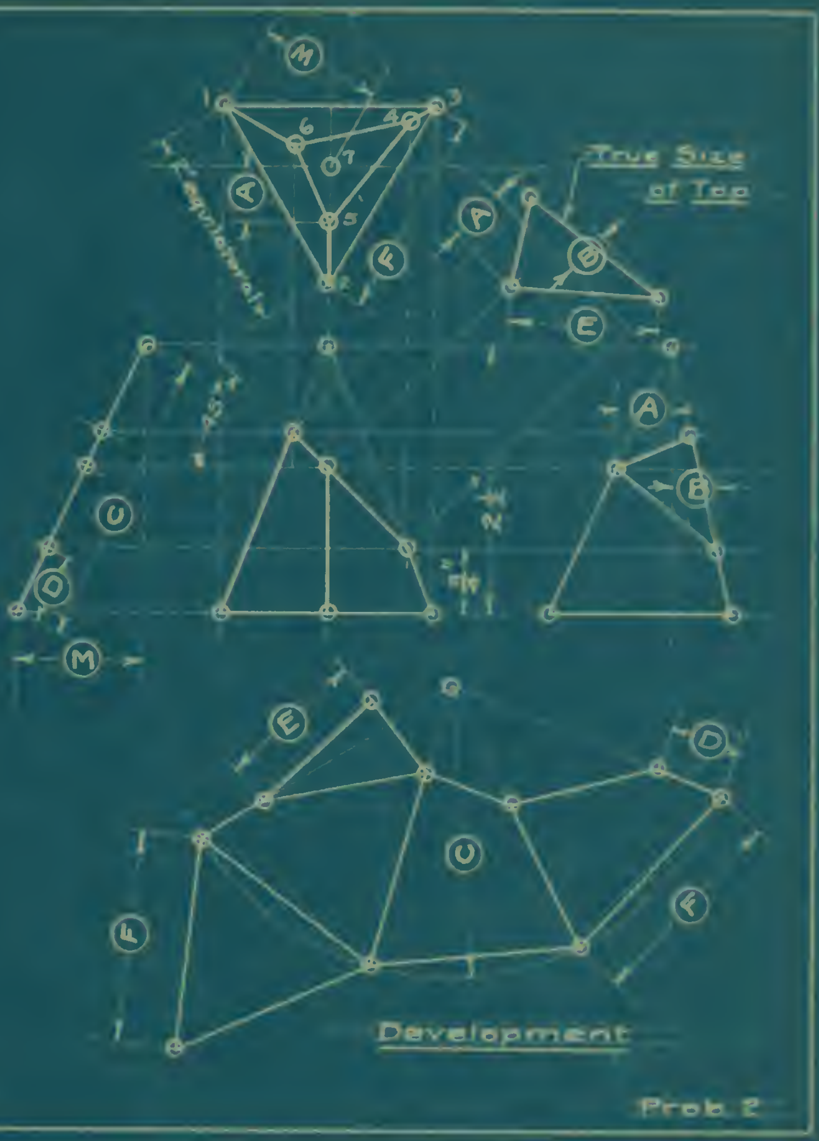
" a^1b^1 = **T. V.** " "

Revolve bottom (b^1) of line to (c^1).

ac will then be **True Length** of *Line.*

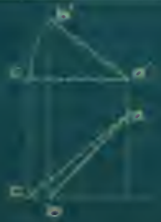


Prob. 1



Prob. 2

Note :



Sheet II

SHEET 12

◆

Intersection of Cone and Planes

Conic Sections

SHEET 12 — INTERSECTION OF CONE AND PLANES

CONIC SECTIONS

DIRECTIONS

I. Use **Auxiliary Cutting Planes** *perpendicular* to *axis* of Cone.

These will cut the surface of Cone in *Circles* (**T.V.**); in *Straight Lines* (**F.V.**).

Points of intersection, on the *Surface* of the *Cone*, of the above Planes and the *Main Cutting Planes* can then be identified in both views, giving us the required curve of intersection.

(Further construction, *True Sizes*, etc., as indicated.)

As many Auxiliary Planes can be used as found necessary.
In this problem they may be taken about ¼ inch apart on **F.V.**

II. The procedure of the previous sheets in regard to *Pencilling*, *Dimensions*, *Reference Points*, *Inking*, etc., is to be followed out on this sheet.

Select at least 5 Reference Points other than those given on blue print.

NOTES

A. *Planes* cutting the *Surface of a Cone*, at different angles, produce the various **Conic Sections** shown on Sheet 12.

(*a*) *Plane parallel to axis of Cone* — **Hyperbola.**

(*b*) " " " *slanting Element* * — **Parabola.**

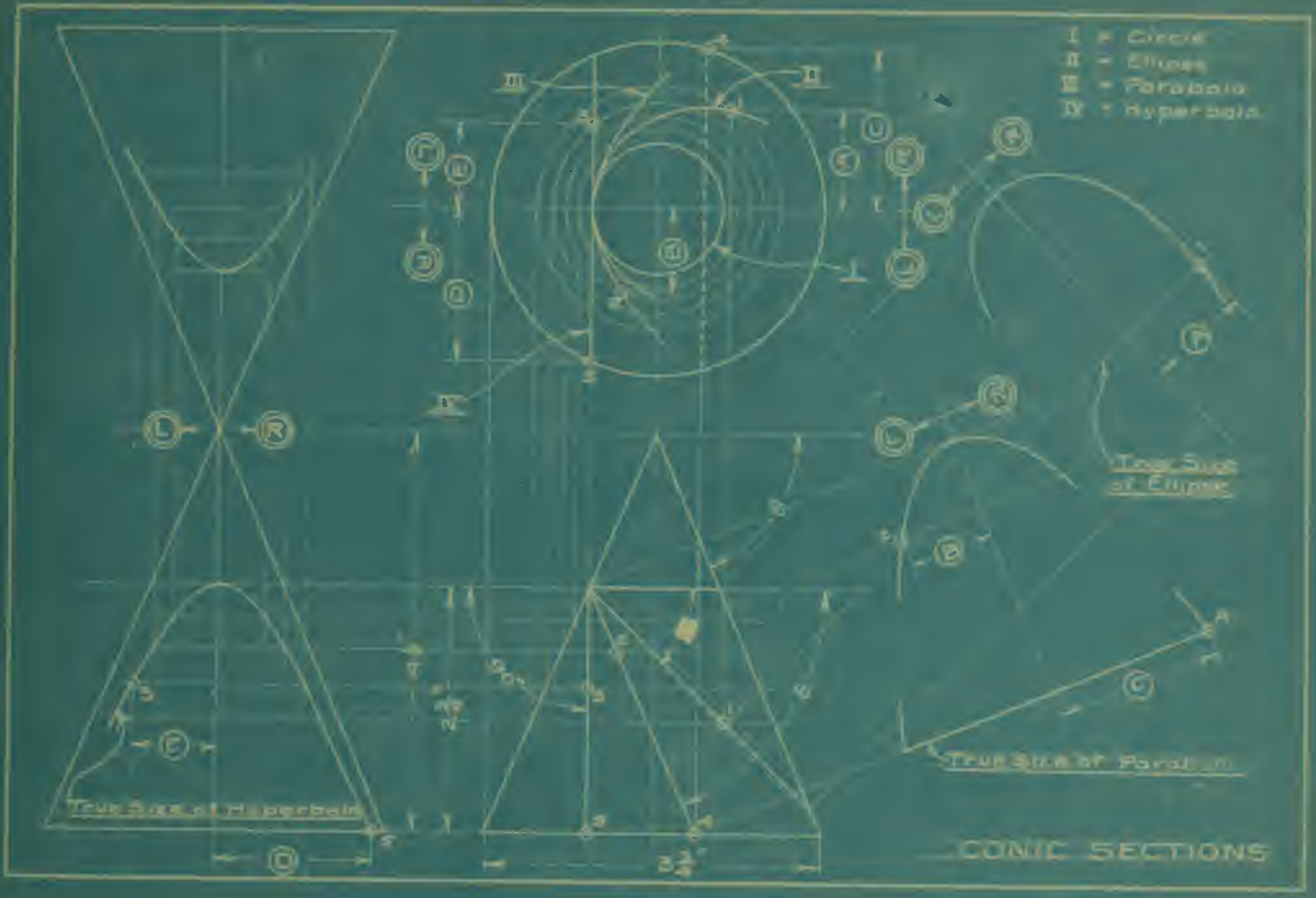
(*c*) " *crosses Cone* — **Ellipse.**

(*d*) " *perpendicular to axis* — **Circle.**

Note: In the case of the *Hyperbola* we get *two curves*, the second one inverted, if we consider the plane to cut the Cone produced above the apex.

Further consideration of the *Conic Sections* is left for *Analytical Geometry.*

* See Page 45–I–*b*.



CONIC SECTIONS

Sheet 12

SHEET 13

Intersection of Cone and Plane

Alternate Method

SHEET 13 – INTERSECTION OF CONE AND PLANE

ALTERNATE METHOD

DIRECTIONS

I. (*a*) Make ϕ same as for Sheet *12*.

(*b*) Use *Vertical* **Auxiliary Planes** through axis of Cone. These will cut the surface of the cone in *Straight Lines* (in all three views).

These lines are called "**Elements**" of the Cone.

(*c*) Points of intersection, on the *Surface* of the *Cone*, of the above Planes and the *Main Cutting Plane* can then be identified in all three views, giving us the required curve of intersection. (Construction as indicated.)

II. (*a*) Lay out arc for *Development*. *Radius = Slant height of Cone*. *Length of arc = Circumference of base of Cone.*

(*b*) In laying off points on Development, remember that the *true lengths* (**E**, **F**, etc.) must be taken as found by method shown in **F.V.** (See Page 39–**C.**)

III. Take at least 5 *selected Reference Points*. Procedure same as hitherto.

The *Elements* can be lettered, as indicated, for convenience of identification during Construction.

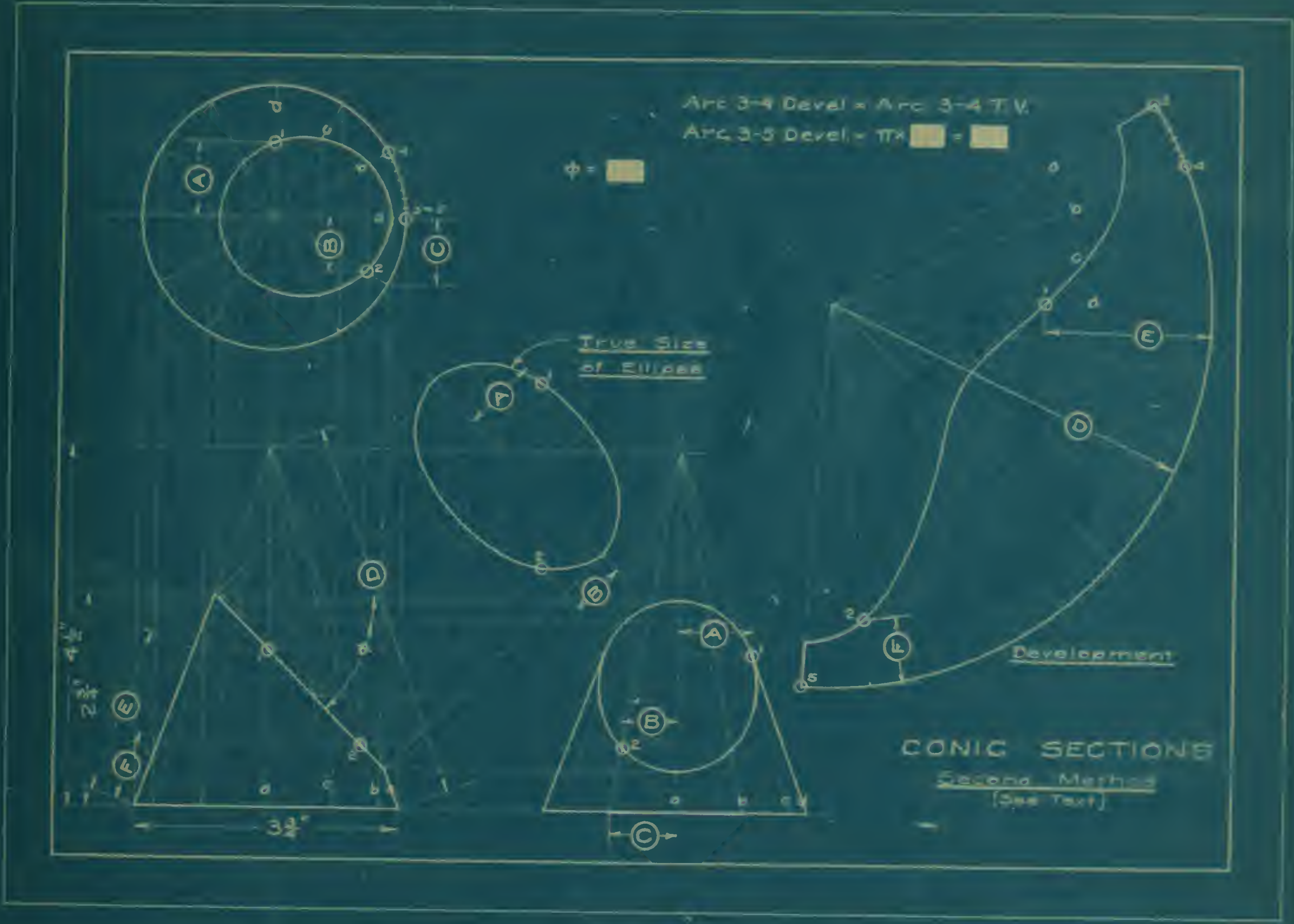
NOTES

A. As long as the *Main Cutting Plane* passes entirely *across* Cone, any angle of ϕ will give an *Ellipse.*

If ϕ is the same as on Sheet *12*, the true size of ellipse, as well as its projections, should be the same by this method as by the previous one. Test by tracing the curve.

B. All the other *Conic Sections* given on Sheet 12 can be obtained equally well by this second method.

C. This second method is much more convenient than the first when a Development of the Cone is desired.


Arc 3-4 Devel = Arc 3-4 T.V.
Arc 3-5 Devel = π×
φ =
True Size of Ellipse
Development
CONIC SECTIONS
Second Method
(See Text)
A
B
C
D
E
F
a
b
c
d
1
2
3
4
5
3½"

Sheet 13

SHEET 14

Intersection of Cone and Hexagonal Prism

Nut for Bolt

SHEET 14 – INTERSECTION OF CONE AND HEXAGONAL PRISM

NUT FOR BOLT

DIRECTIONS

I. Method of construction indicated on blue print. (As in *Conic Section* sheet we use *Auxiliary Planes*.)

(*a*) Make **Complete Top View.**

(*b*) Procedure as hitherto.

II. When completed and **approved** this sheet is to be *traced*.

(*a*) Use **Shade Lines*** on all views, in accordance with principles given on PAGE *82*–SHEET *H* (*in Inking only*).

(*b*) Omit all *Construction Lines*, *Reference Numbers*, and *Letters* in Inking.

(*c*) Add Dimension and Centre Lines (*Red-light*).

(*d*) Arrows, Figures, and Lettering (*Black*).

* It is more convenient to draw first all unshaded lines; then open pen a little and draw all shaded lines.

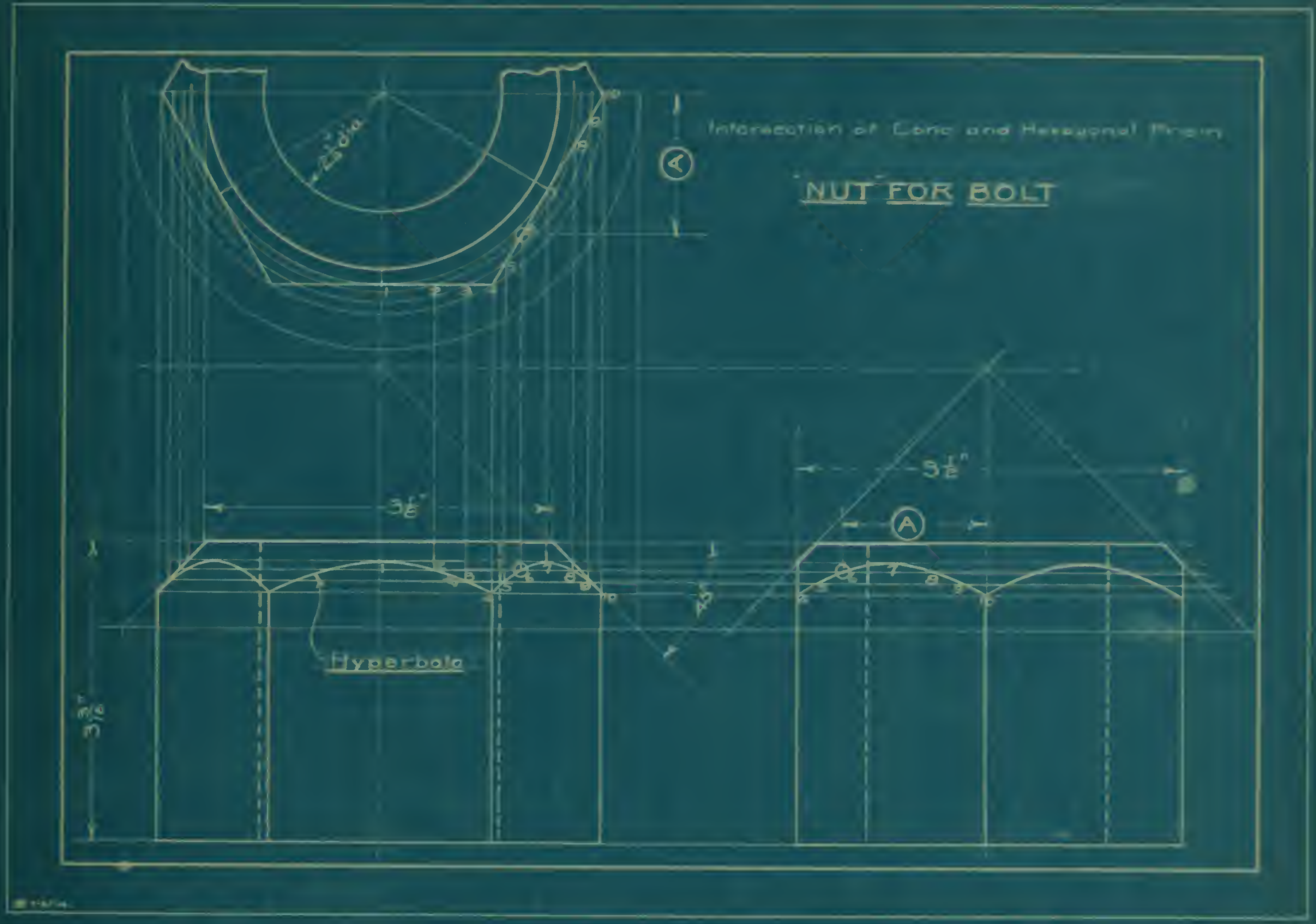
NOTES

A. The curve developed on the *Front Face* is evidently a portion of an **Hyperbola.**

The same curve appears on the slanting faces, in both front and side views, but in both cases more or less foreshortened.

Intersection of Conic and Hexagonal Prism

NUT FOR BOLT



SHEET 15

Intersection and Development of Prisms

SHEET 15 — INTERSECTION AND DEVELOPMENT

OF

PENTAGONAL AND TRIANGULAR PRISMS

DIRECTIONS

I. (*a*) Block out the 3 Views each of the Pentagonal and Triangular Prisms (both Equilateral).

(*b*) Work out Projection of *Intersection*.

(*c*) Work out Developments as indicated.

II. (*a*) Procedure as hitherto.

(*b*) Add at least 2 selected Reference Points (other than those given on the blue print) on all Views and Developments, and define them by small circles and appropriate Reference Dimensions.

(*c*) Number, without adding Circles, all other points, as indicated.

(*d*) Substitute for "**?**" in Developments the proper dimensions taken from the corresponding lengths in the original views.

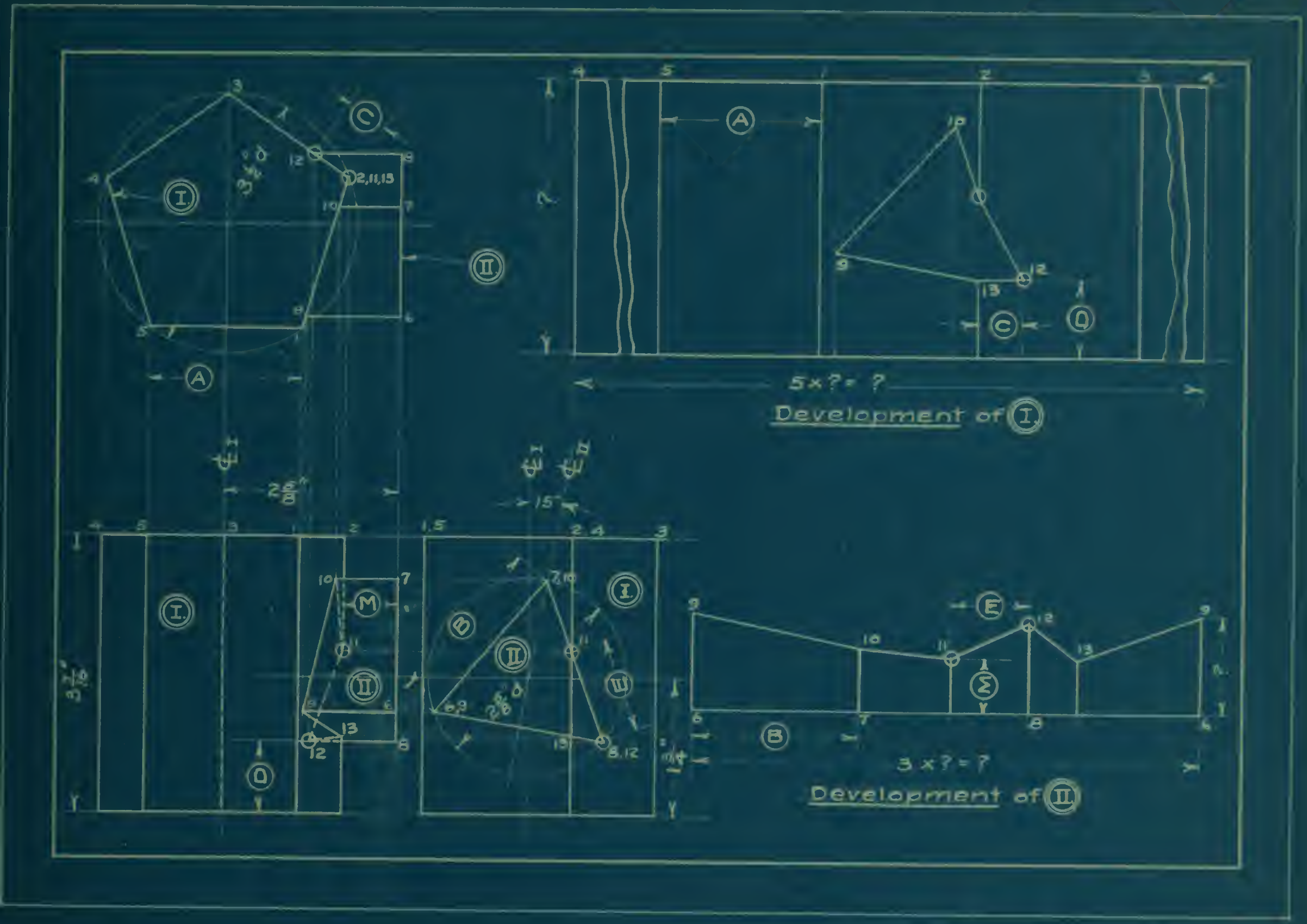
III. Reproduce Developments on piece of Duplex Paper; cut out and fold to produce original subject.

NOTES

A. As on Sheet 11 the purpose of Development is to obtain *Patterns* which, when cut and properly folded, will produce the original subject drawn.

B. In **T. V.** the apex of the Triangular Prism starts from **7** and is intercepted at **10** by Pentagonal Prism. Now the **F. V.** of this apex must be the same length — i. e. : **7–10.** We can, therefore, locate point **10** in **F. V.**

Similarly for other points of intersection.


I
II
A
B
C
D
E
M
W
3 1/4" D
2 5/8"
2 5/8" D
1.5"
3 7/16"
1 1/4
2,11,15
6,9
7,10
8,12
5 × ? = ?
Development of I
3 × ? = ?
Development of II

SHEET 16

Intersection and Development of Cylinders

DIRECTIONS

I. Method similar to that of Sheet *15*, with the addition of *Auxiliary Planes* used in Conic Section Sheet.

II. (*a*) Block out 3 views of Large Cylinder — **I.**

(*b*) Block out **F.V.** and **E.V.** of Small Cylinder — **II.**

(*c*) Work out **T.V.** and **R.V.** of **II.**

(*d*) Work out Projection of Intersection.

(*e*) Draw Developments.

III. (*a*) In Development of II cut cylinder at some other point than that shown on blue print.

(*b*) Number and letter all points (given in R.V.) in all Views and Developments.

(*c*) Add at least 2 selected Reference Points on all Views and Developments, and define them as hitherto.

(*d*) Dimensions "?" are to be supplied by scaling the drawing.

(*e*) In stepping off arcs use *very small intervals.*

(See Page 23–Fig. 2.)

NOTES

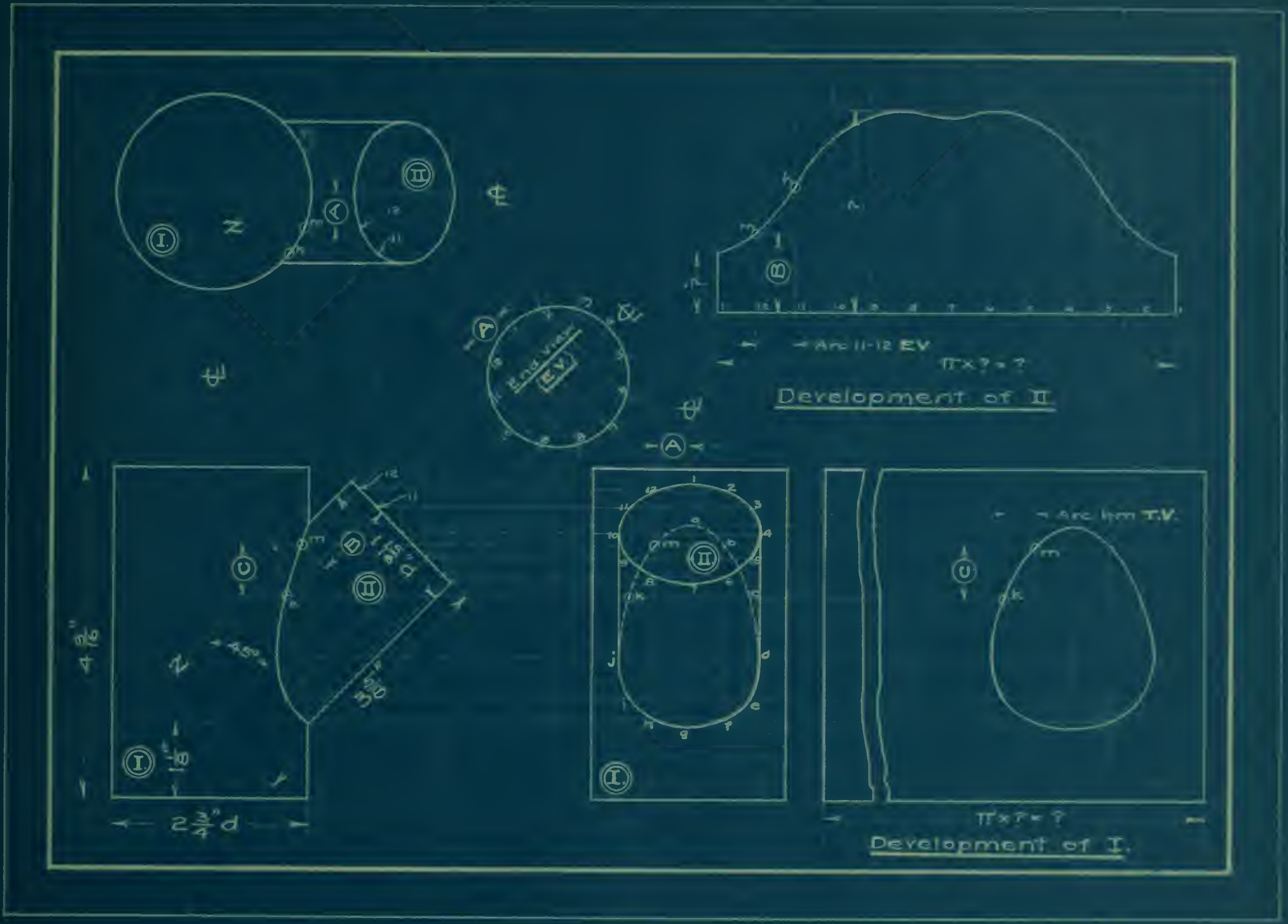
A. An Auxiliary Plane parallel to axis of Small Cylinder (as **12–m–h**, **R.V.**) will cut a line (**12–z**) on latter's surface in **F.V.** by projecting horizontally. This line will appear in **T.V.** at distance (**A**) from *C.L.*

Now, in **T.V.** this line is intercepted at **m** by surface of Large Cylinder; by projecting down, therefore, we identify point **m** in **F.V.** This gives one point of intersection. The others can be found similarly.

The Auxiliary Plane would also cut surface of small cylinder on *under side*. Each plane, therefore, will give two points of intersection.

B. Auxiliary Planes can be taken at will, but for convenience in development it is best to make arcs **1–2**, **2–3**, etc., on **E.V.** all *equal.*

In laying out Development of **II** take length of circumference and divide into proper number of parts.


I.
II
A
N
m
h
12
11
B
h
m
n
I
12
11
10
9
8
7
6
5
4
3
2
1
← Arc 11-12 EV
π × ? = ?
Development of II
A
End View
E.V.
A
C
B
II
m
k
1 15/16" d
45°
3 5/8"
4 3/16"
1 1/8"
I
2 3/4" d
1
2
3
4
12
11
10
a
b
c
d
e
f
g
h
i
j
k
m
II
I.
← Arc hm T.V.
m
k
C
π × ? = ?
Development of I.

SHEET 17

Isometric Drawing

SHEET 17 — ISOMETRIC DRAWING

DIRECTIONS

I. Draw first the *Orthographic Views.*

Note that the scale is **4** inches = **1** foot.

II. Develop the *Isometric Drawing* from the Orthographic Views. Start with Point **1**, and build up the figure by locating *successive Points* (method indicated by reference dimensions) and then join the points by the required straight or curved lines.

When small curves cannot be conveniently drawn with the French Curve, a radius can often be found to approximate the required curve, and compasses can be used.

III. Show Point **1** as on blue print. Then add at least 3 selected Reference Points other than those given, and define their position by Reference Dimensions, both in Orthographic Views and in Isometric Drawing.

IV. When completed and approved the sheet is to be *traced.*

In inking: —

(*a*) Omit all construction lines and all Reference Figures and Letters.

(*b*) In Isometric Drawing omit also all *axes.*

(*c*) Add *numerical* dimensions and lettering.

(*d*) Use method of inking given for previous tracings.

NOTES

A. **Isometric Drawing*** is a method of showing, in one View, what in *Orthographic Projection* requires two or more views. It resembles a distorted *Perspective Drawing.*

B. Briefly, in Orthographic Projection we have 3 axes which can be called *Width* (**W**), *Depth* (**D**), and *Height* (**H**), respectively.

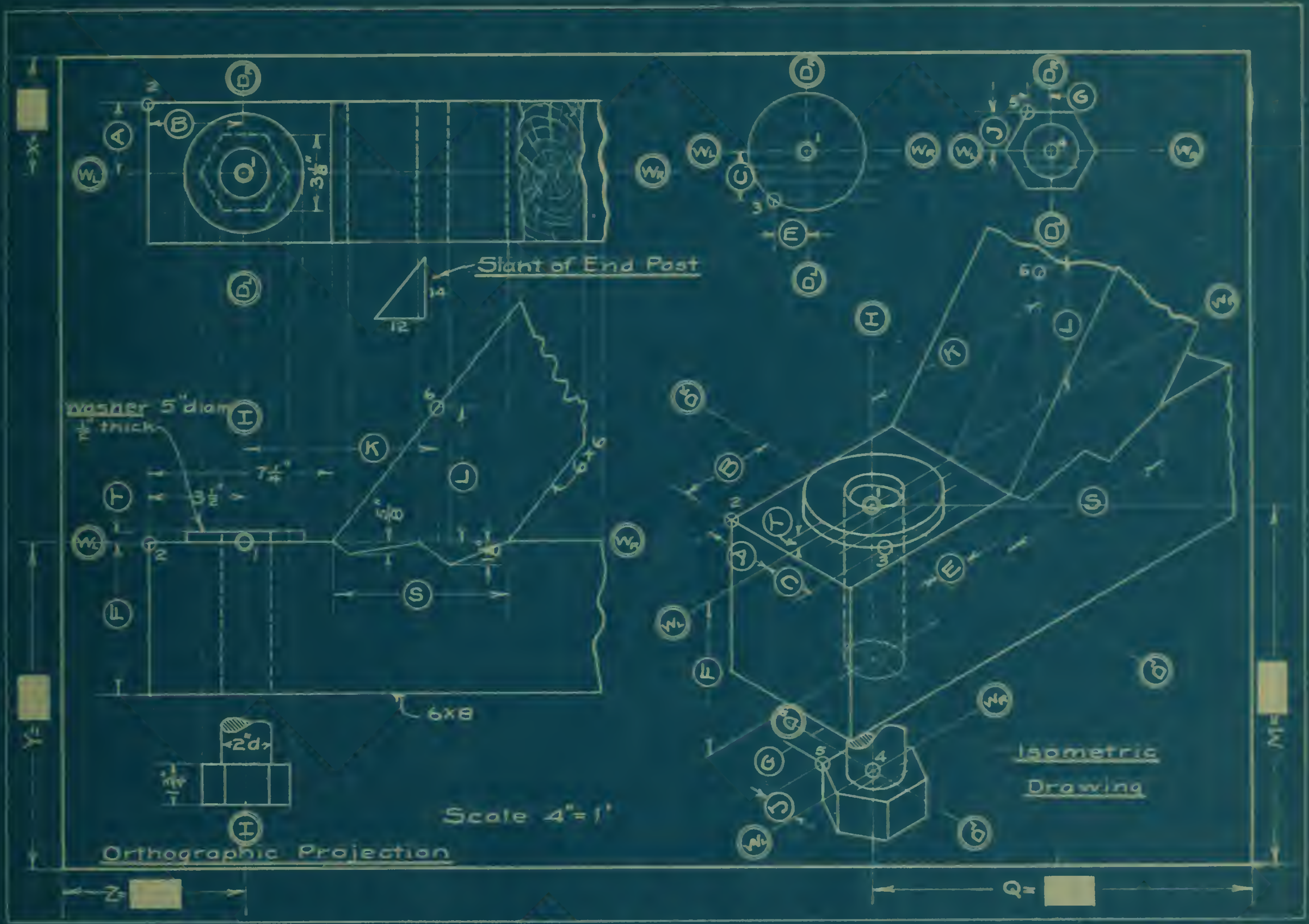
In Isometric Drawing these are all combined in one View by imagining an object tipped at an angle. This tipping is such as to make the **W** and **D** axes each form an angle of **30°** with the *horizontal*, while the **H** axis remains *vertical.*

Any distance parallel to any one of the 3 axes in Orthographic Projection is then laid off in the Isometric Drawing in its *true length* parallel to the corresponding axis.

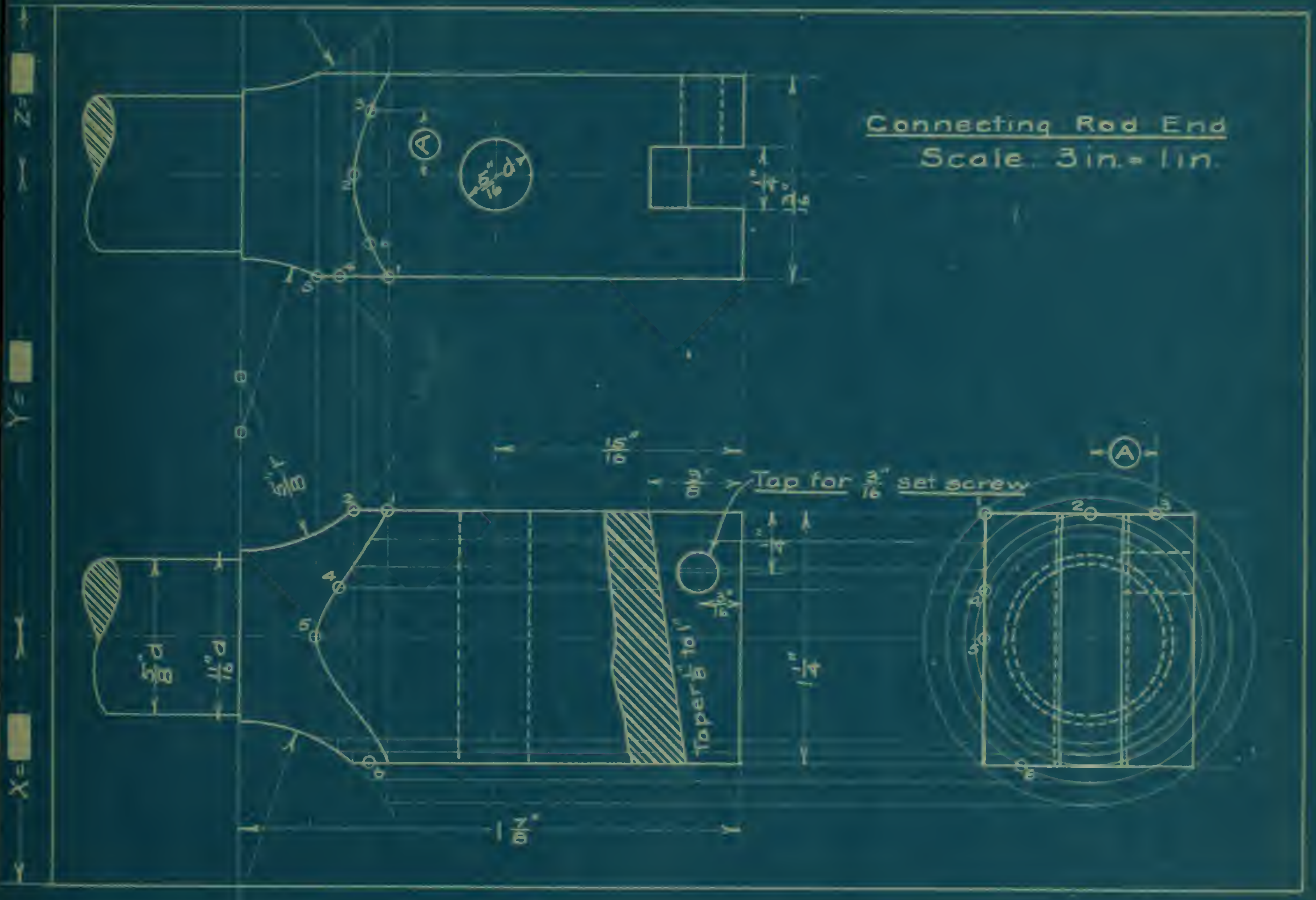
By joining points thus located we develop an Isometric View.

C. It follows from above that *only those lines which are parallel to any one of the 3 axes* are shown in their *true length* in an Isometric View.

* A distinction must be noted between the above described Isometric "*Drawing*" and strict Isometric "*Projection*." In the latter the lengths of all lines parallel to any one of the axes would be 0.8165 times their true length. In practice, however, this correction is rarely made, and the true lengths instead of the corrected ones are used as above described.

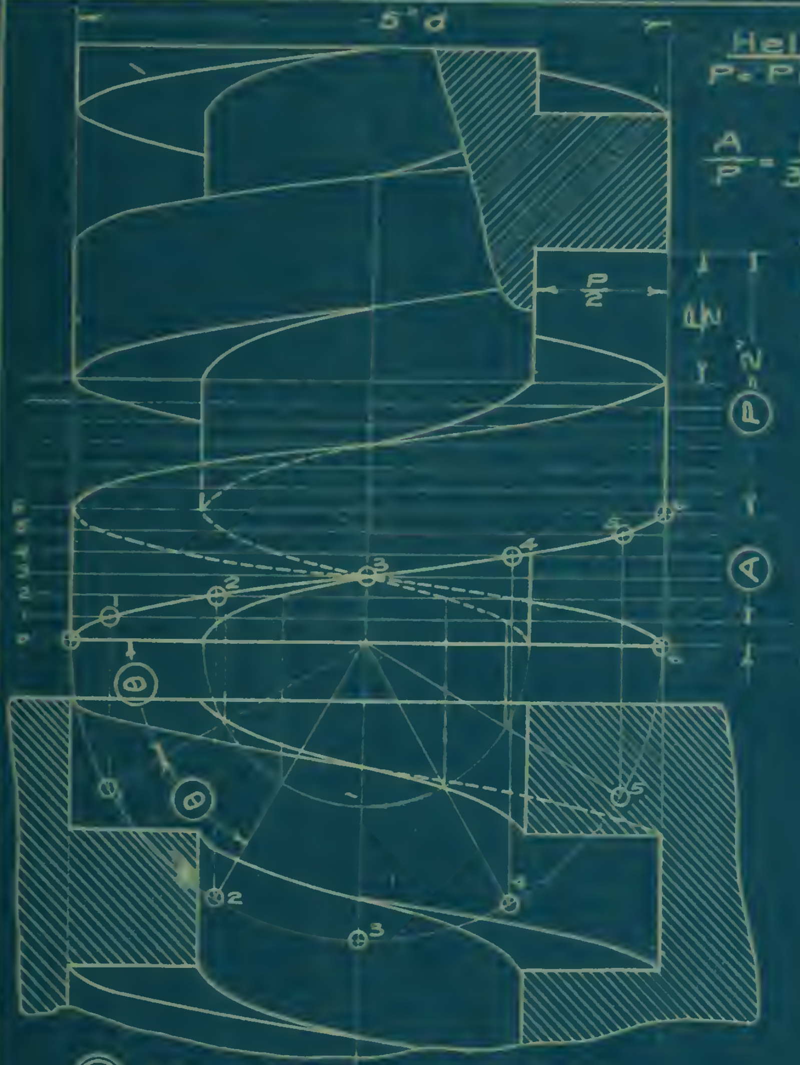


Note: Timber sizes are stated thus: 2×4 (2"×4"), 6×6, 6×8 etc.
In this exercise draw a 6×8 (8" side vertical)



Connecting Rod End

Scale 3in. = 1in.



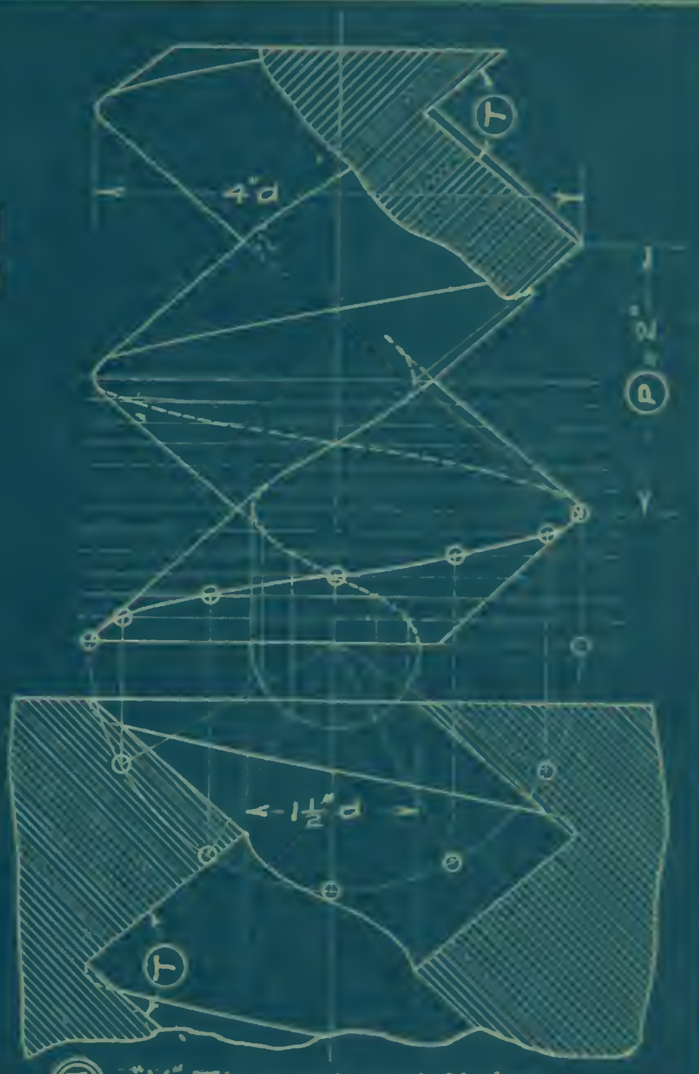
Ⓘ Square Thread and Nut.

Helix
P = Pitch

$$\frac{A}{P} = \frac{\theta}{360^\circ}$$

A =

θ =



Ⓘⓘ "V" Thread and Nut.

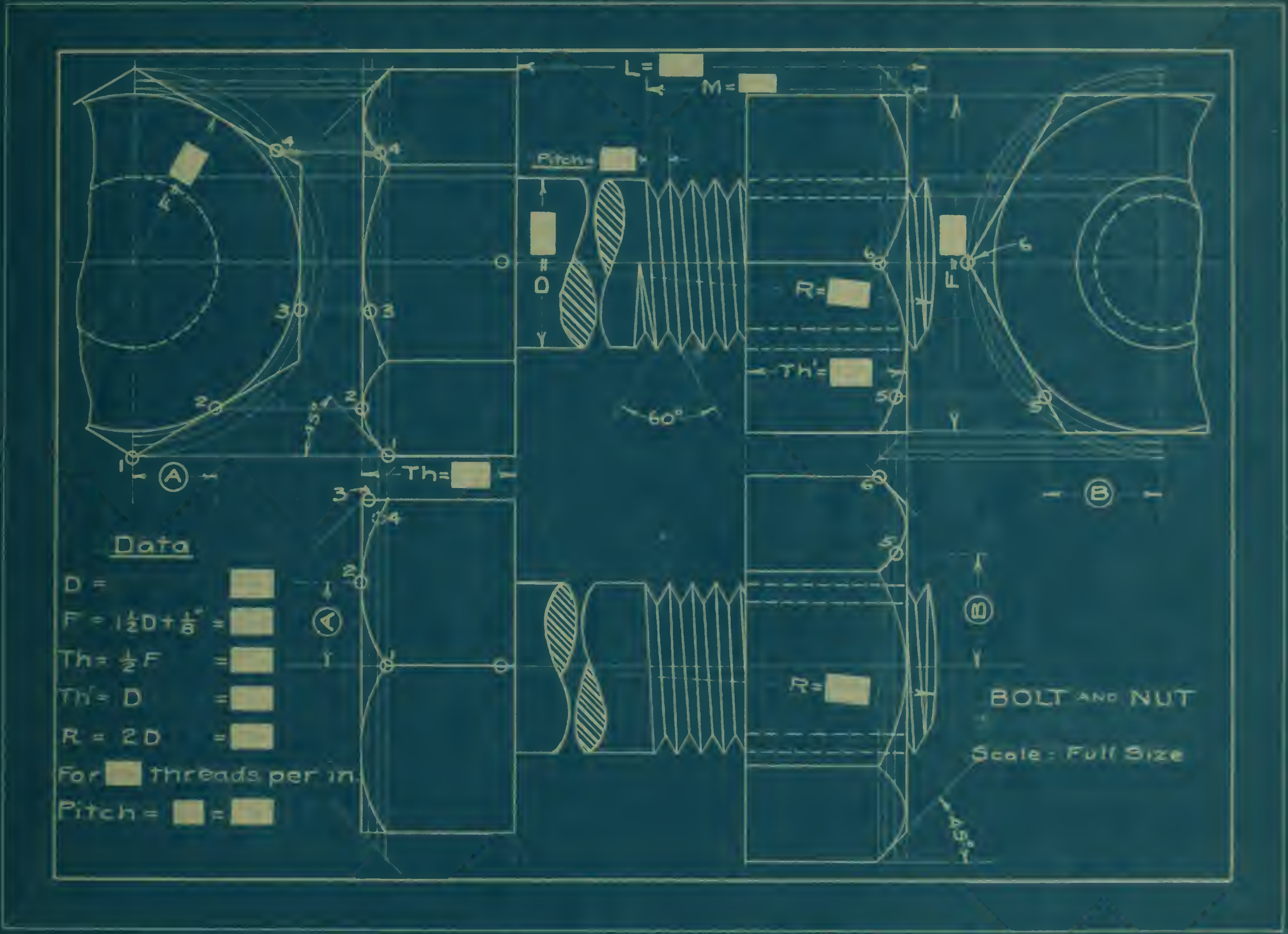
Ⓘ (1) θ = some convenient divisor of 360° - make it to give at least 8 points in semi-circumfrence.

(2) Make Ⓐ to correspond (3) Record values of Ⓐ and θ selected.

Ⓘⓘ (1) Ⓣ = "angle of thread" In this case Ⓣ = 77° 20'.

(2) For standard threads Ⓣ usually equals 60° [See Sheet K - II Page 84]

Sheet 19



Data

D =
F = 1½D + ⅛" =
Th = ½F =
Th' = D =
R = 2D =
For threads per in.
Pitch = =

BOLT AND NUT

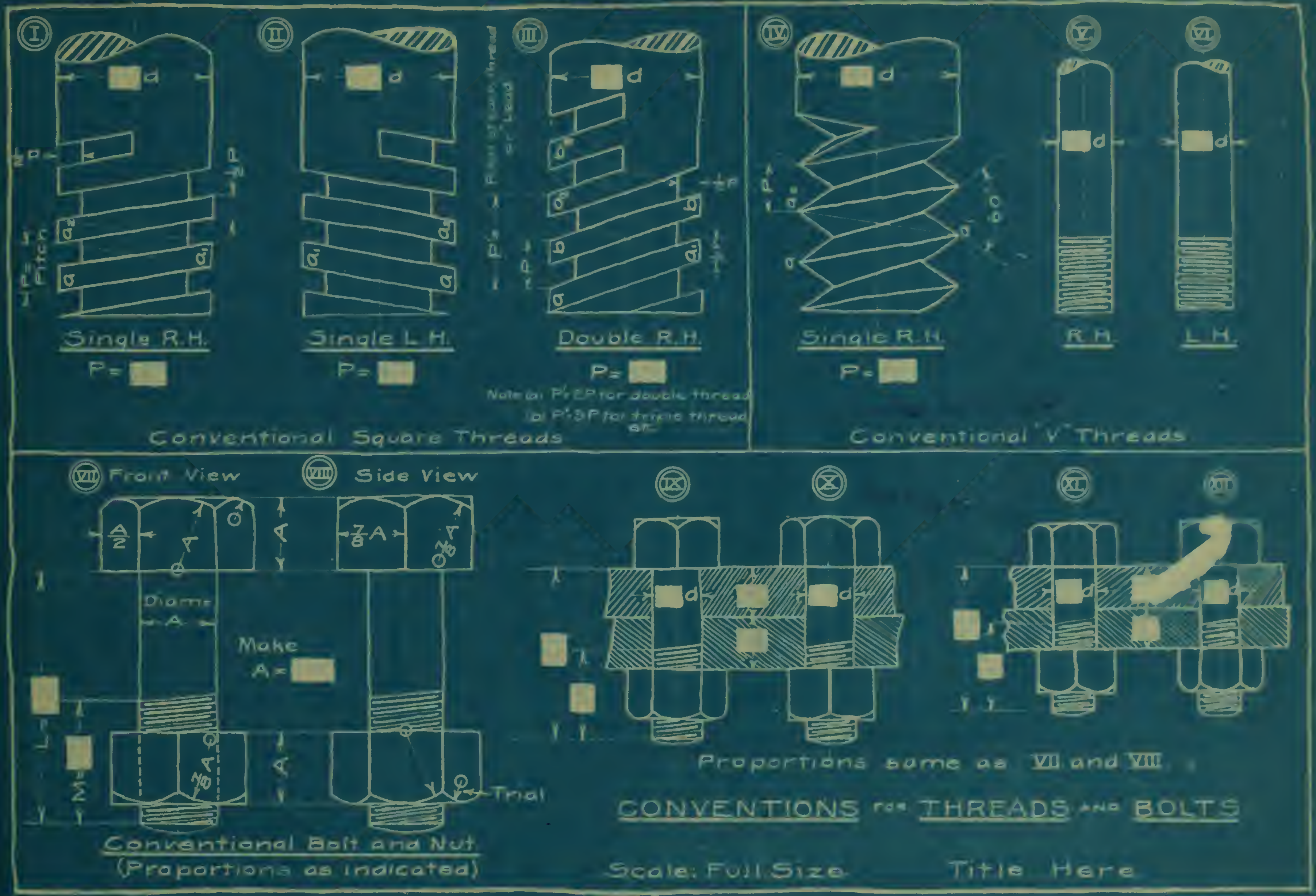
Scale: Full Size

Note: (a) Proportions given for bolt head and nut are the usual standard in practice.

(b) For number of threads per inch (standard for given diameter) see Sheet K-1 page 84

Sheet 20.

FREE HAND ON SKETCHING PAD Stage 1- Block out | Black Pencil | Stage 3 - Distinct Lines - (Red pencil).
Stage 2-Complete all drawings | Stage 4 - Figures + Lettering - (Black).


I
II
III
IV
V
VI
d
½P
½P
P= Pitch
a
a₁
a₂
b
b₁
b₂
P' = Pitch of each thread or Lead
P
Single R.H.
Single L.H.
Double R.H.
Single R.H.
R.H.
L.H.
P=
P=
P=
P=
Note (a) P'=2P for double thread
(b) P'=3P for triple thread etc.
Conventional Square Threads
Conventional "V" Threads
VII Front View
VIII Side View
IX
X
XI
XII
A/2
A
⅞A
Diam.= A
Make A=
L
M
⅞A
Tinal
Conventional Bolt and Nut
(Proportions as indicated)
Proportions same as VII and VIII.
CONVENTIONS FOR THREADS AND BOLTS
Scale: Full Size
Title Here

Note: I, II - R.H.=Right Hand; L.H.= Left Hand Thread.

III - Note that a, a_1, a_2 is one distinct thread and b, b_1, b_2 a second, quite independent of the first.

IV - Large threads are represented thus.

V, VI - Small threads are represented thus.

VII, VIII - In drawing a standard bolt only 3 dimensions are given: (1) Diameter (2) L= Length (3) M= Distance threaded.

VII, X and XI show bolt heads across "corners".

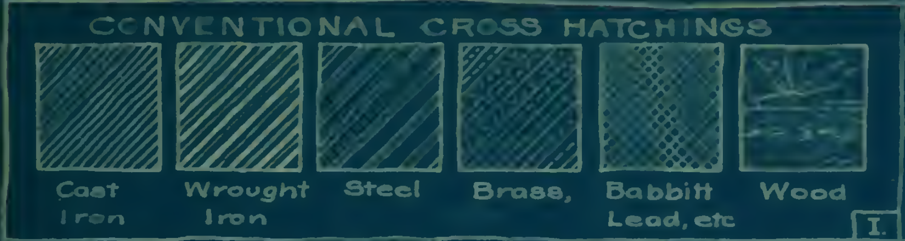
VII, IX and XII show bolt heads across "flats".

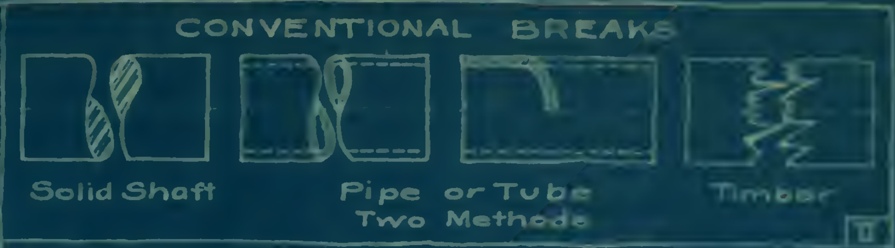
FOR STANDARDS SEE SHEET K - IV, page 84

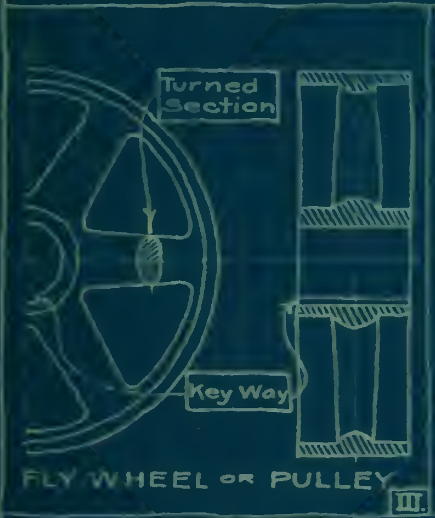
Sheet 21

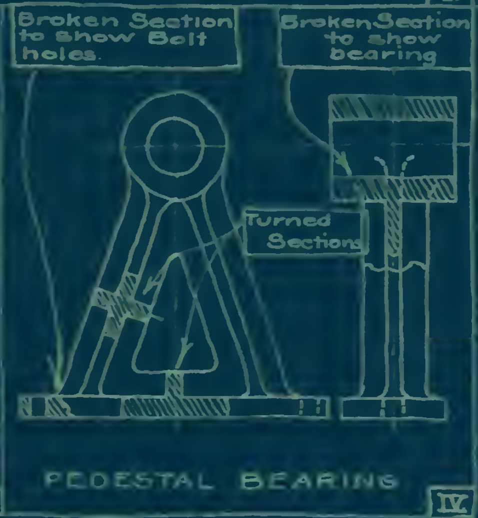
For further Cross Hatchings - see page 82 III.

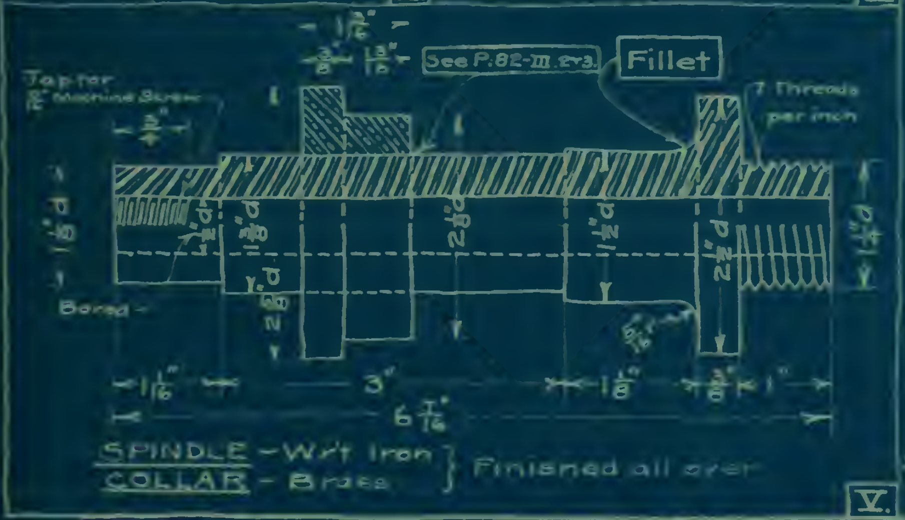
(2) By Stages as on Sheet 2.

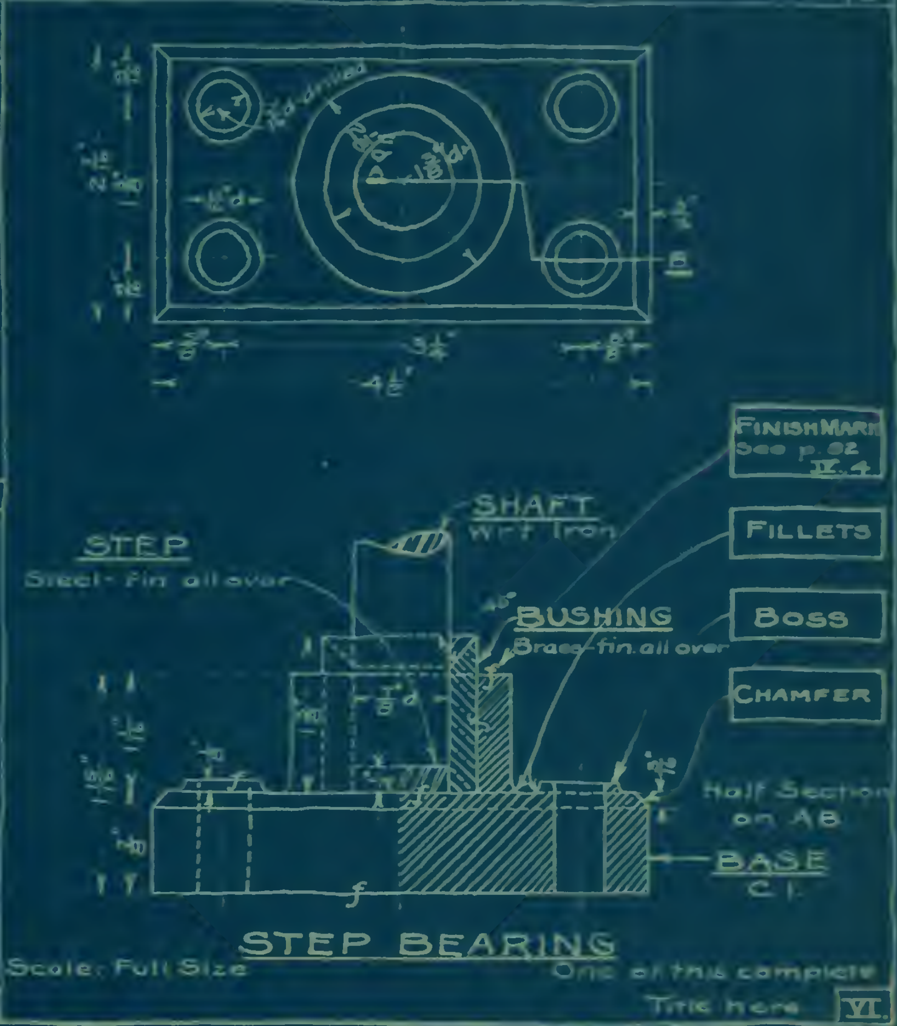







Broken Section to show Bolt holes.
Broken Section to show bearing
Turned Sections
PEDESTAL BEARING
IV.




drilled
3¼"
4½"
B
FINISH MARK See p.82 IV.4
SHAFT Wr't Iron
STEP Steel - fin. all over
BUSHING Brass - fin. all over
FILLETS
Boss
CHAMFER
Half Section on AB
BASE C.I.
f
STEP BEARING
Scale: Full Size
One of this complete Title here
VI.

Note: (1) III. & IV. show conventional methods of sectioning.

(2) V shows all necessary dimensions in one view.

(3) VI shows (a) Several parts drawn together

(b) Section on given line - with shaft unsectioned.

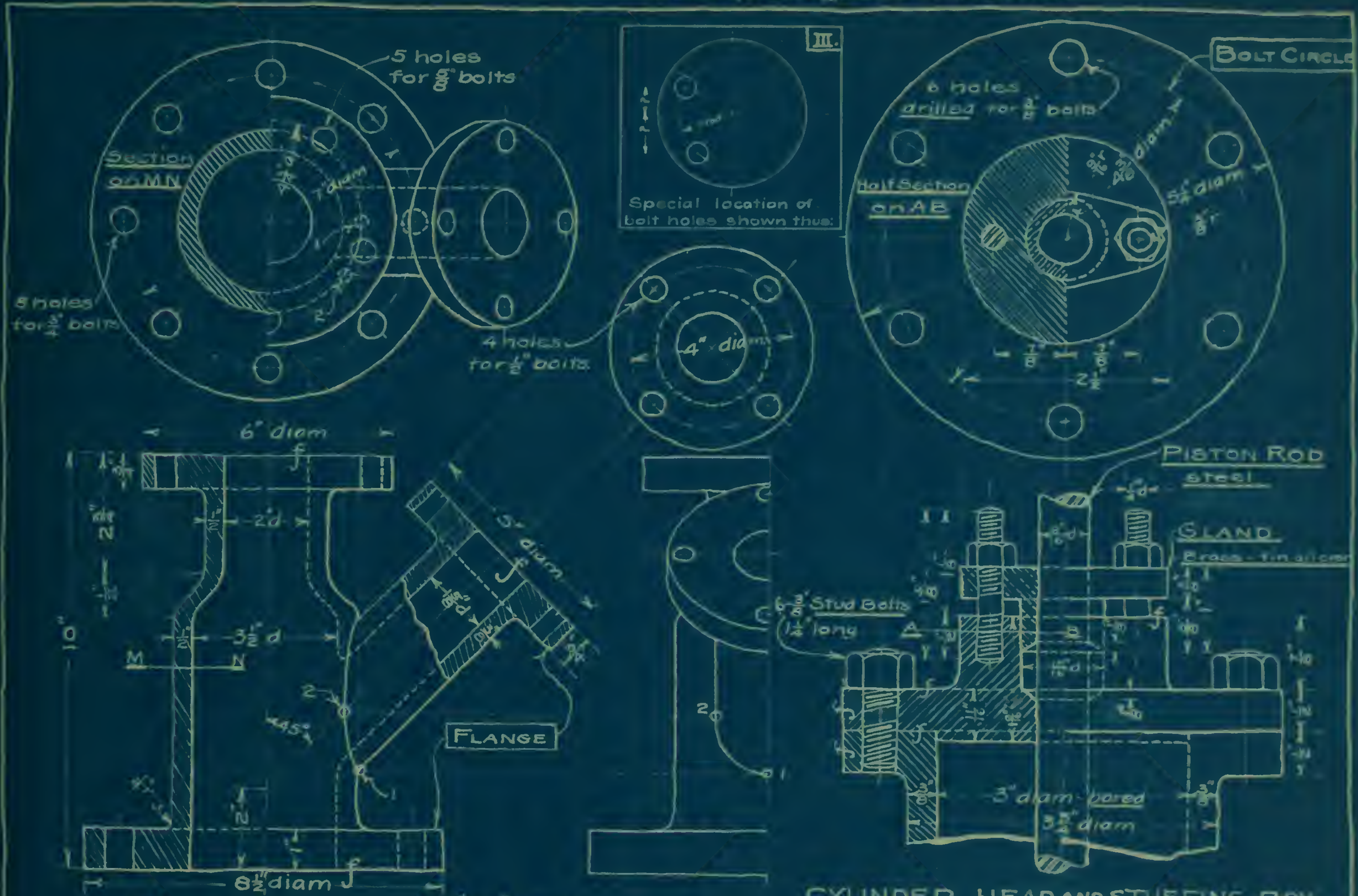
(c) Drilled Holes - Size and Location

(d) Surfaces to be machined by "f"

CHECK CAREFULLY FOR ERRORS IN DIMENSIONS.

SOME DRAFTING CONVENTIONS

Sheet 22.



FLANGED PIPE "Y" C.I.
Scale: Half Size

I.

CYLINDER HEAD AND STUFFING BOX.
Scale: Full Size

Title here

II.

NOTE: This sheet shows.
(1) Method of defining Bolt Holes (I. + II.)
(2) Liberty taken with Projection of Bolt Holes (I + II)
(3) Method of "HALF SECTION" with Rod and Bolts in place (II.)

III is one of many possible arrangements - taken merely for illustration. It would perhaps be better to have the axis of shaft horizontal in front view - its natural position in an engine.

DIRECTIONS FOR SHEET

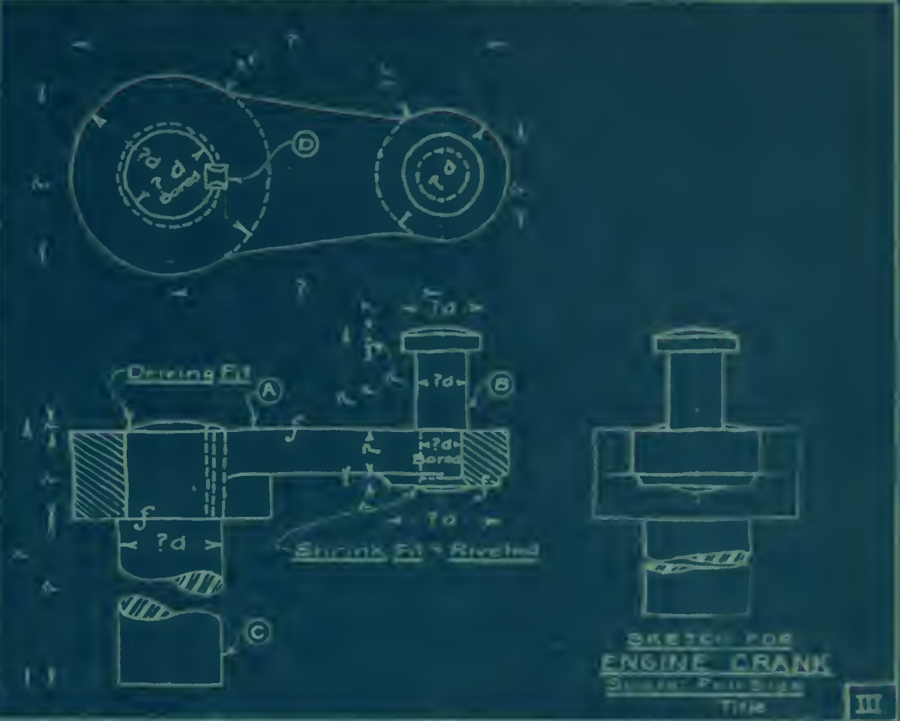
(1) To be drawn FREE HAND ON SKETCHING PAD.
(2) Sketches to be made directly from model (Stage 1&2)
(3) Make selection of views without consulting diagrams below
(4) Add Dimension Lines - Red (Stage 3) consult III this page
(5) Add dimensions, figures and lettering - Black Stage 4 -
(Measure model with rule and calipers)

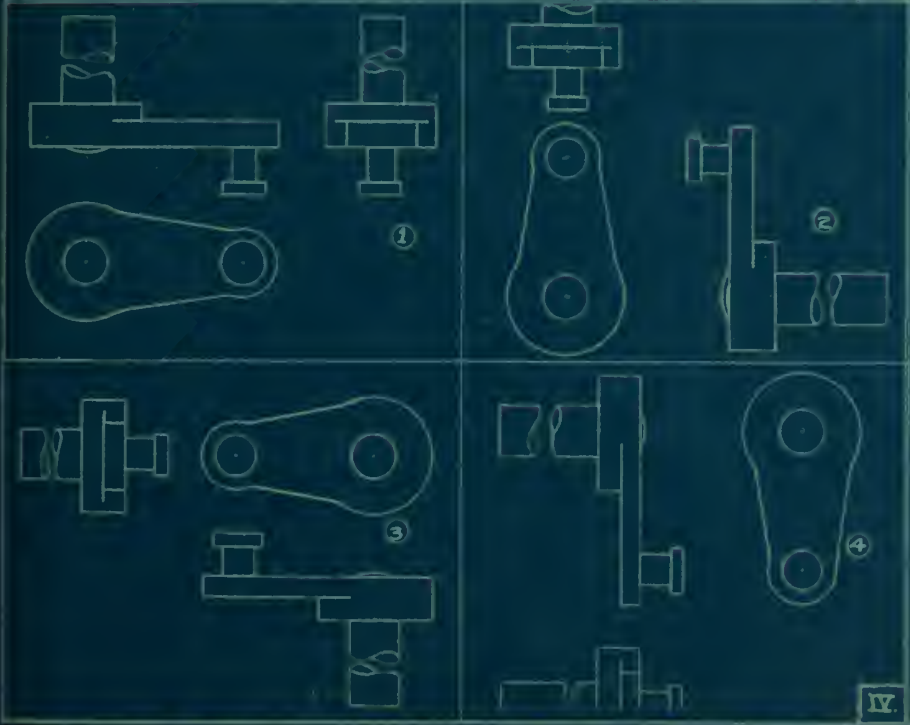
I

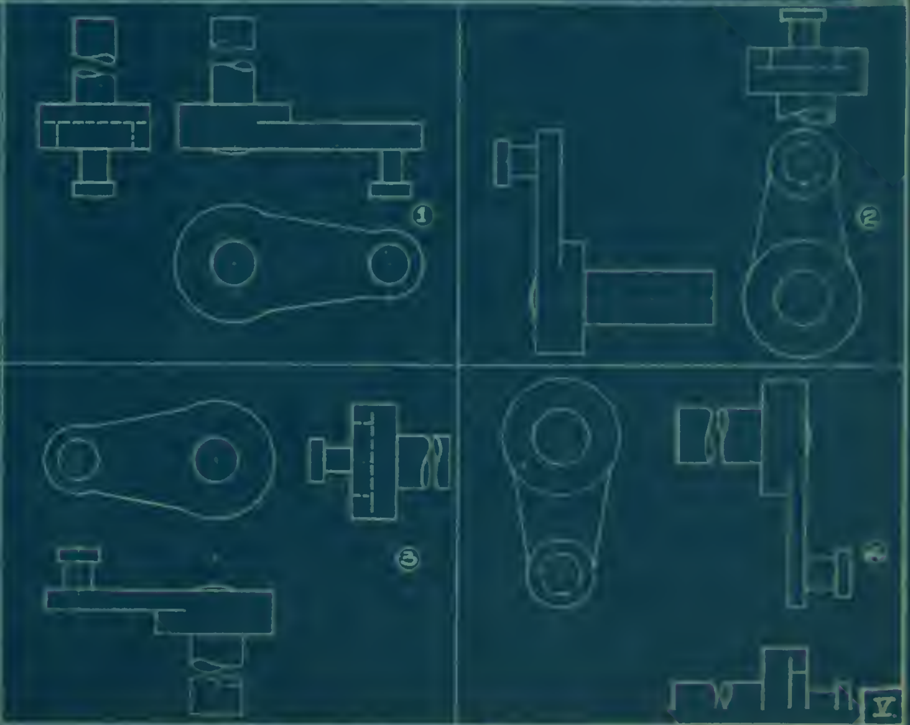
CHOICE AND ARRANGEMENT OF VIEWS

1. Select for **FRONT VIEW** one which gives clearest idea of object.
2. If possible place front view to show object in its natural position.
3. Draw as many other views as are necessary to show object clearly.
4. Select views which show important lines Full and not Dotted.
   NOTE: *Hidden lines (dotted) should be drawn only when they add to the general clearness of the drawing.*
5. ARRANGE ALL VIEWS in accordance with principles of Projection given on earlier sheets.
   ie **T.V.** *above;* **B.V.** *below;* **R.V.** *at right, etc.*
   This is the usual practice in the United States.
6. To avoid confusion, hold object stationary and imagine your own stand point changed for each view, instead of turning the object itself.

II.





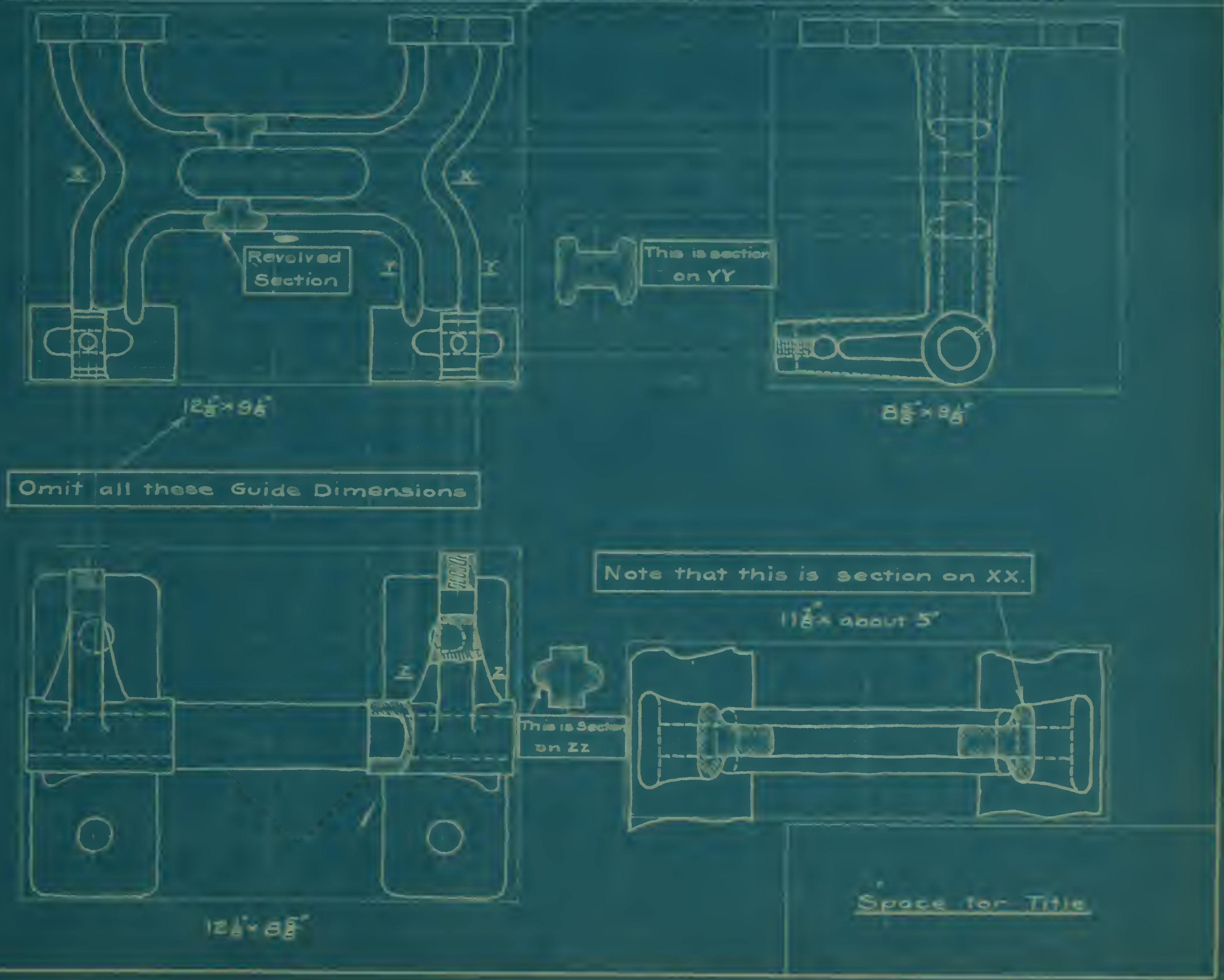


IV. Shows 4 Possible arrangements - all correct. 2 & 4 perhaps best - axis of shaft in natural position

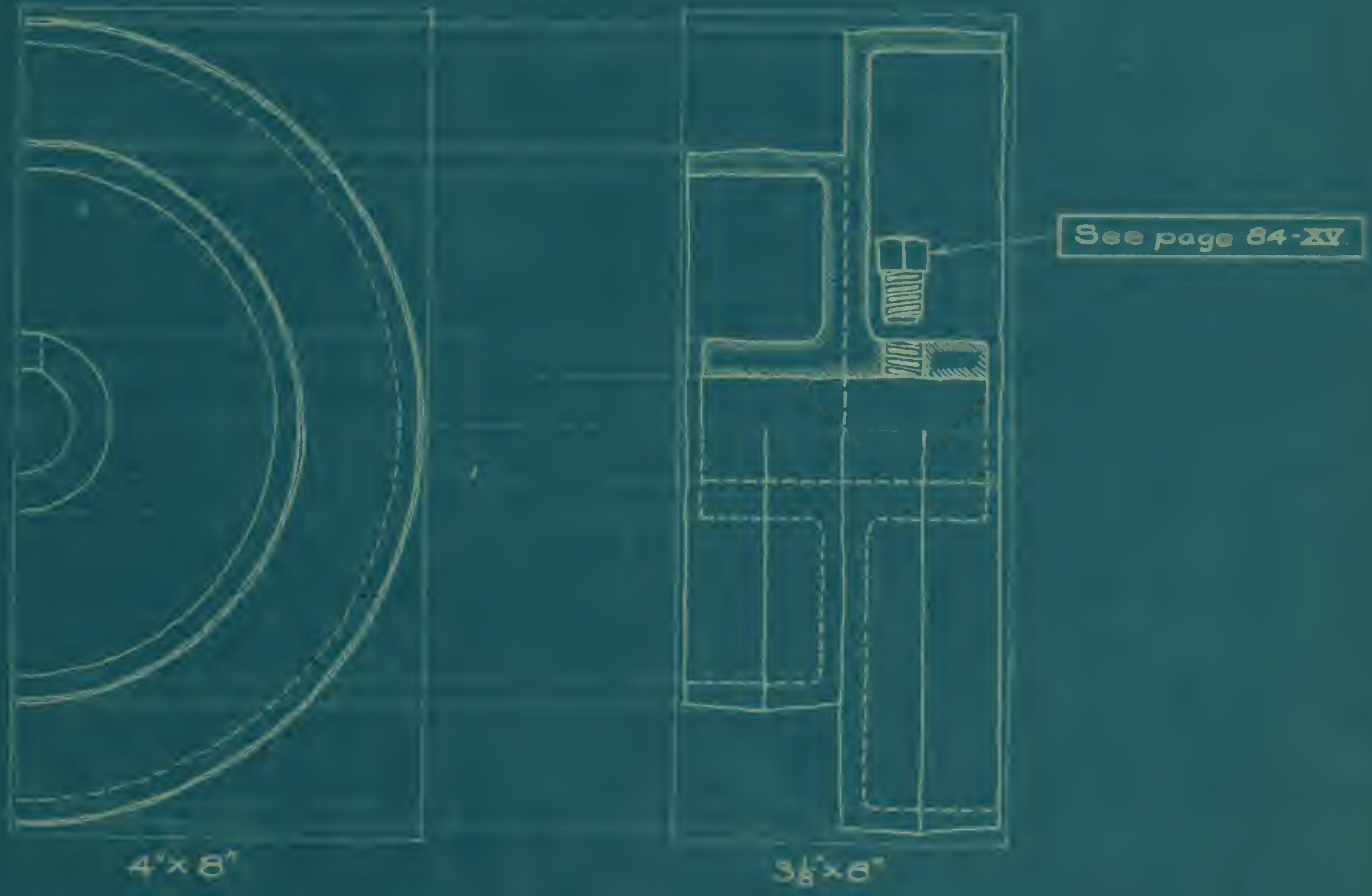
V. Shows 4 other arrangements - also correct but less satisfactory - too many important lines hidden. Sheet 24

Note: Free Hand on Sketching Pad
Stages 1 and 2

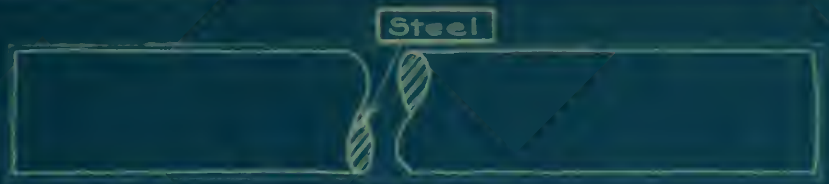
(a) Block out Guide Rectangles lightly – make scale ½ size.
(b) Then work out drawing, developing corresponding parts in the different views at the same time.



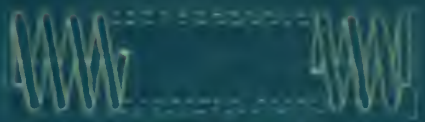
Make Scale Full Size
See Note top of page 66



Space for Title

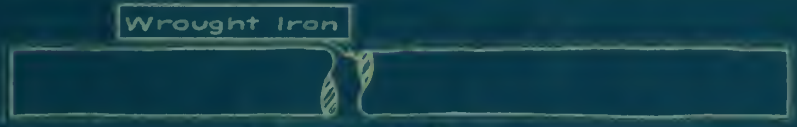


About 6" × 1"

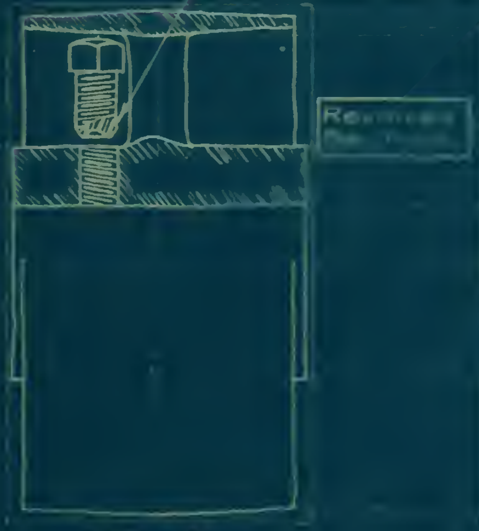


About 4" × 3/4"

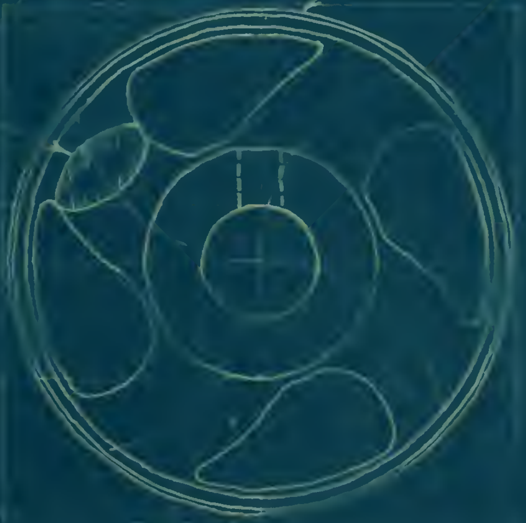
Make Scale: Full Size



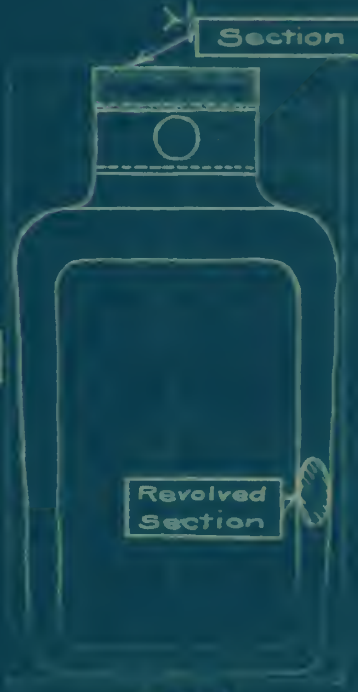
About 6" × 1/2"



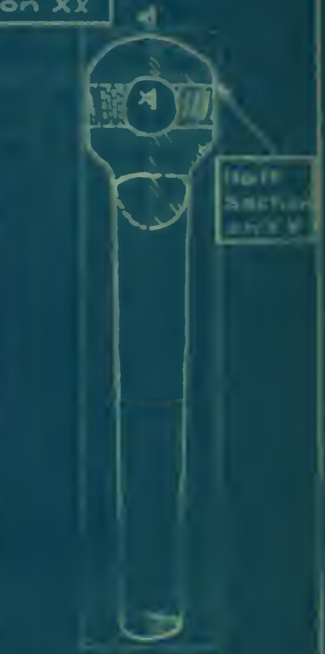
2 7/16" × 4 3/4"



4 3/8" × 4 3/8"



3" × 5 5/16" × 1"

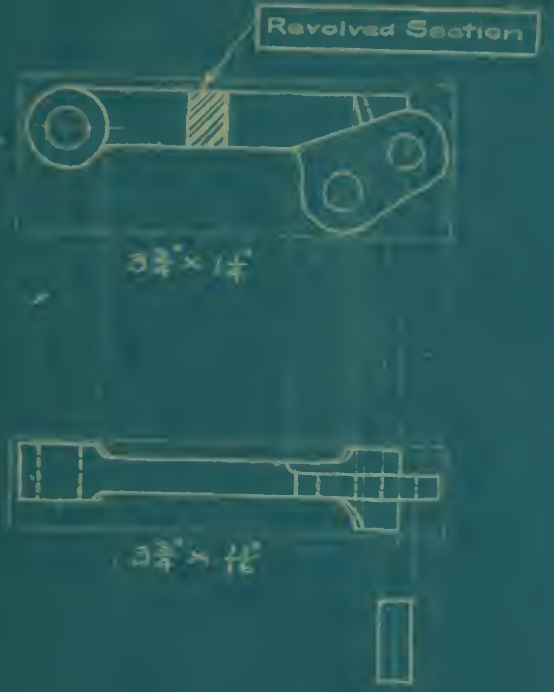


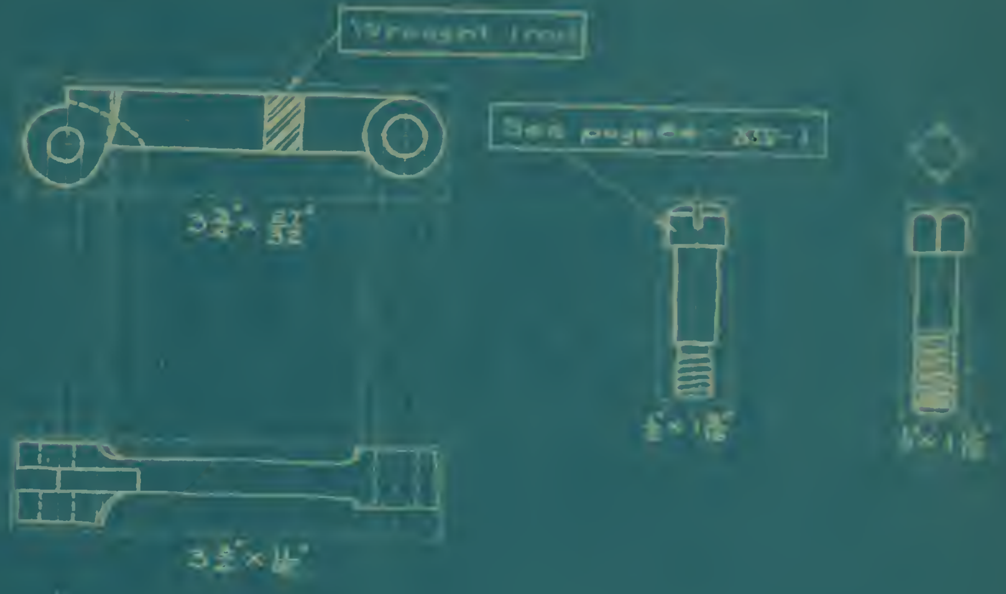
1 5/16" × 5 5/16"

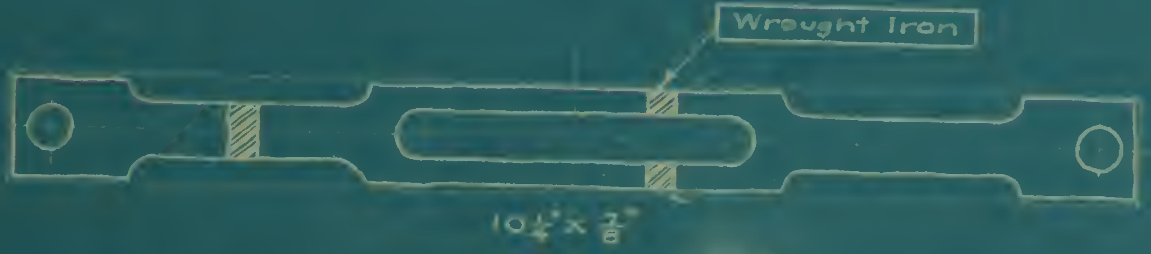
Space for Title

Sheet 25c

Make Scale Full Size

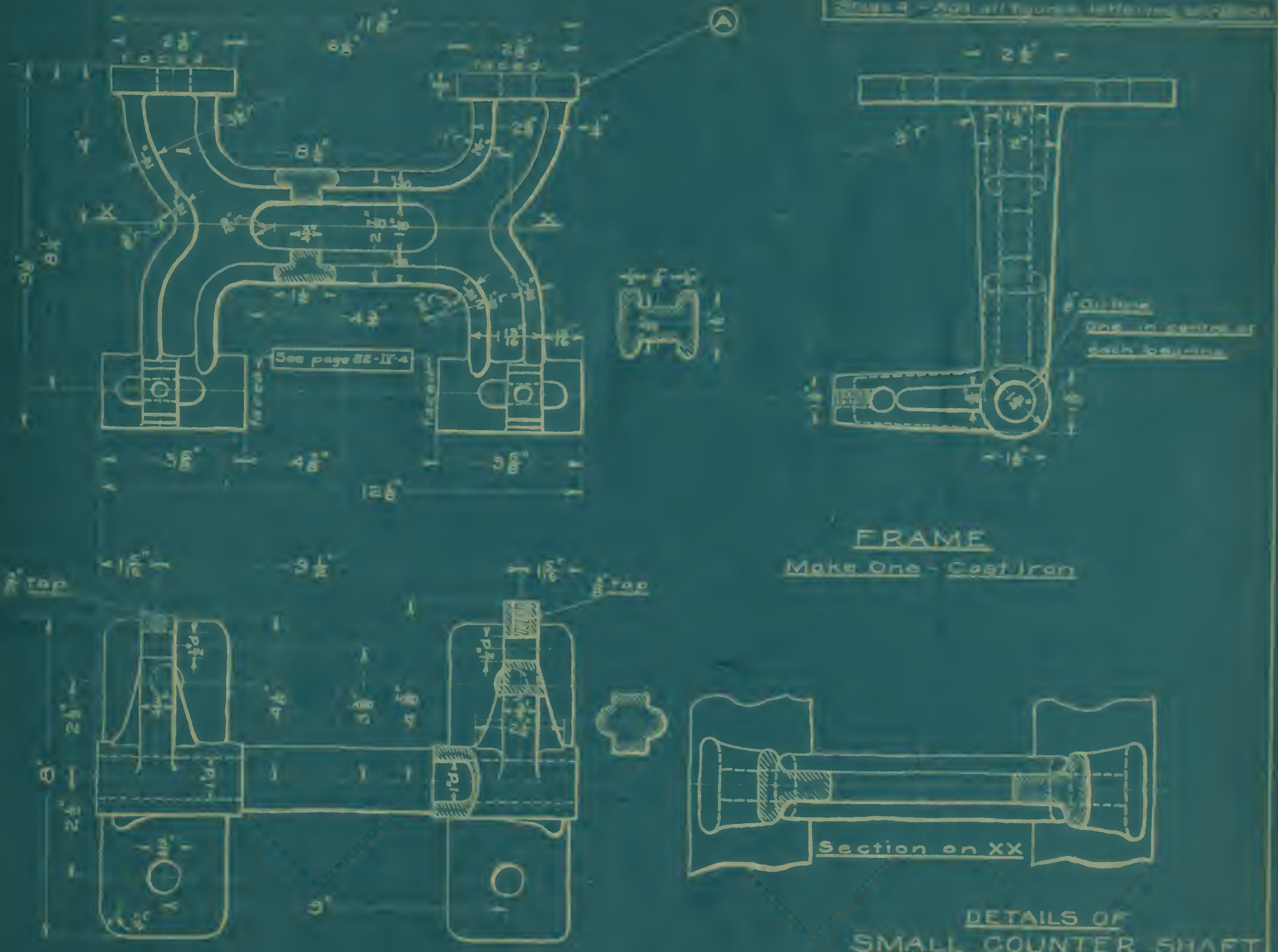






Space for Title

NOTE Stage 3 - Add all dimensions [illegible]
Stage 4 - Add all figures, lettering [illegible]



FRAME

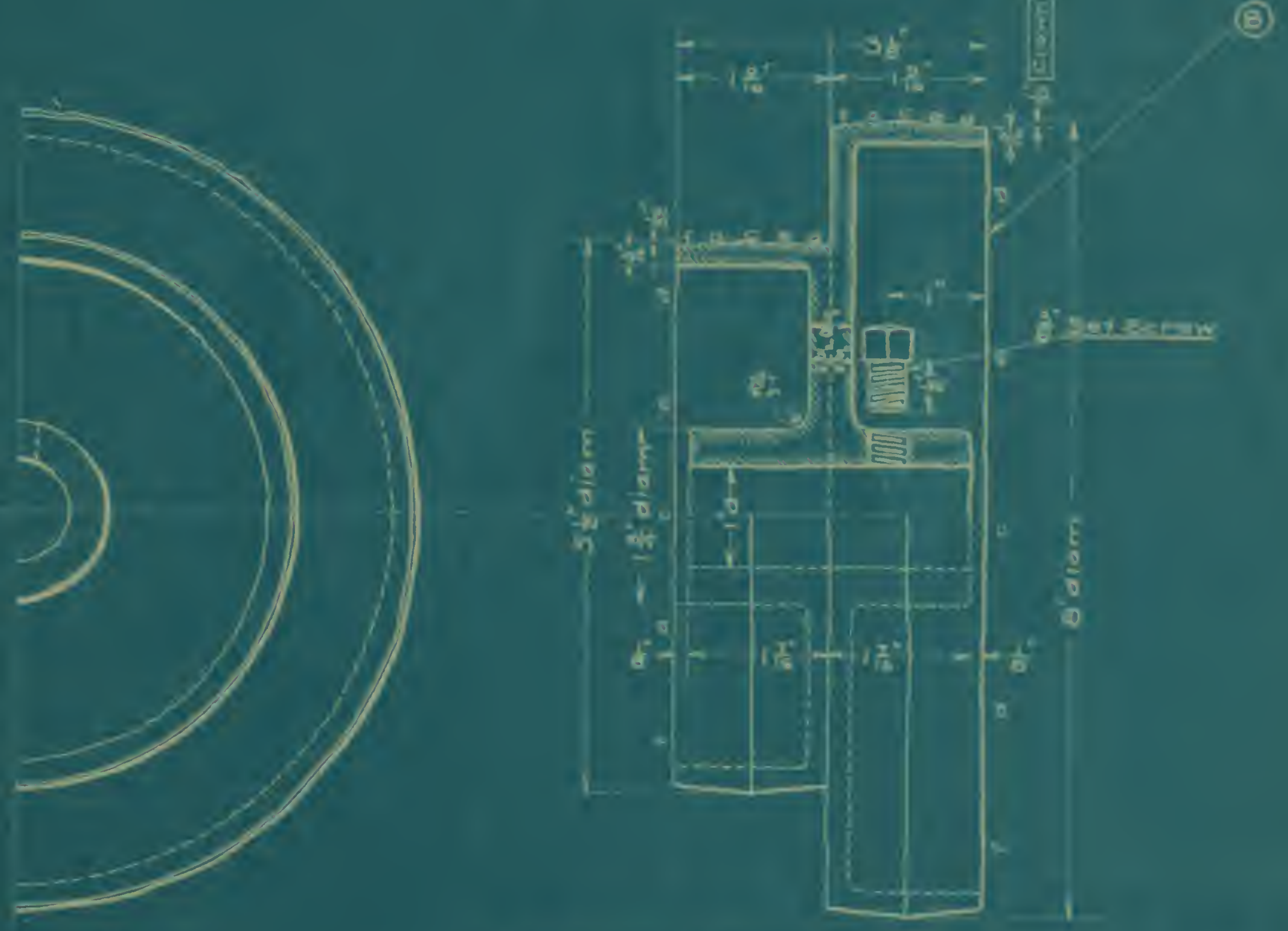
Make One - Cast Iron

DETAILS OF
SMALL COUNTER SHAFT

Scale Half Size

Title here

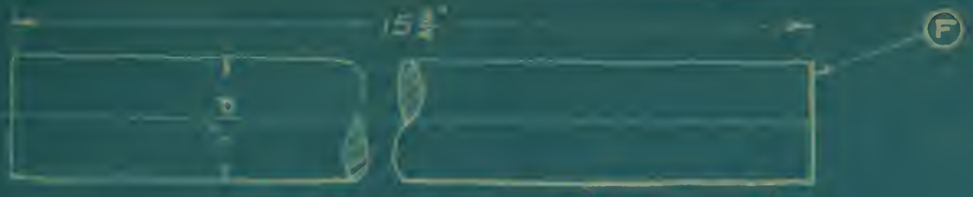
See Note top of page 70.



CONE PULLEY

Make One - Cast Iron

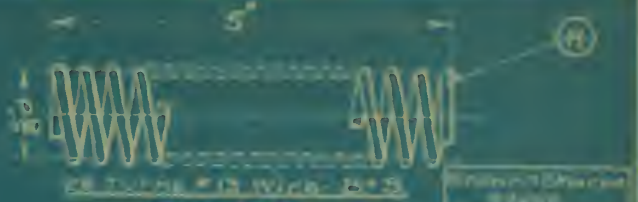
DETAILS OF
SMALL COUNTER SHAFT
Scale: Full Size



SHAFT

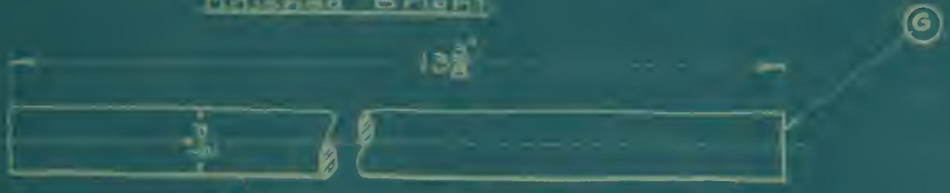
Make One - Steel

Finished Bright



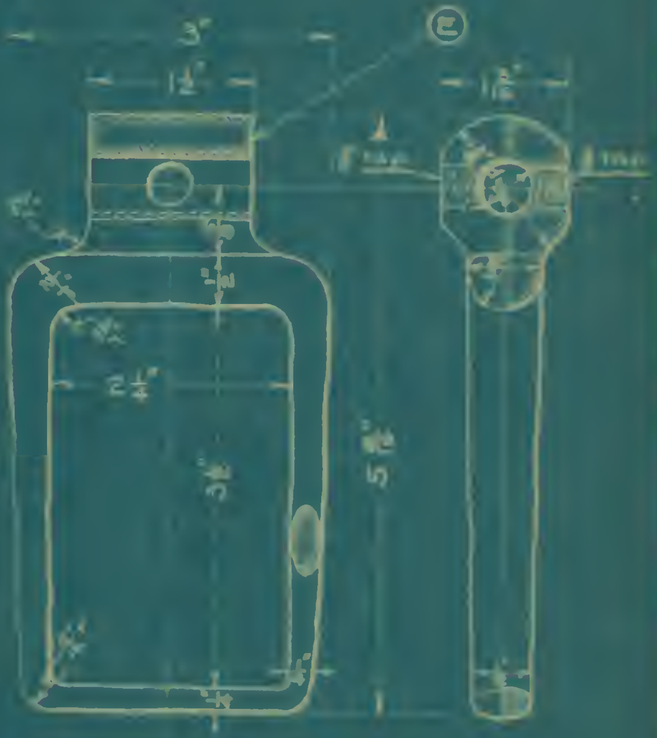
SPRING

Make One - Brass



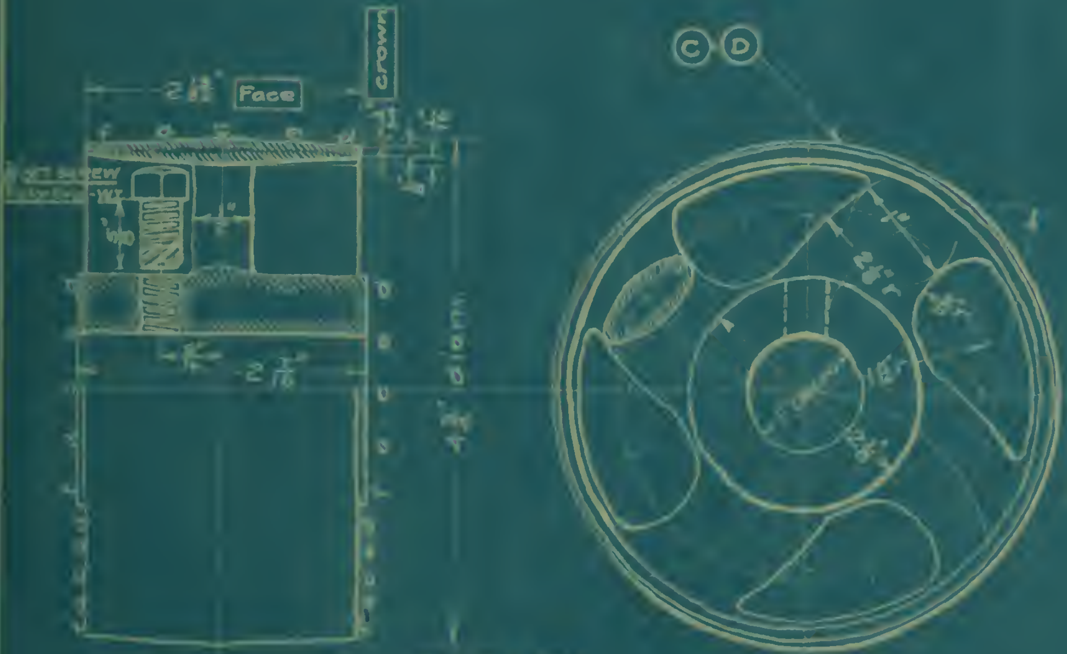
SHIFTER ROD

Make One - W.I.



SHIFTING YOKE

Make One - Cast Iron



PULLEY

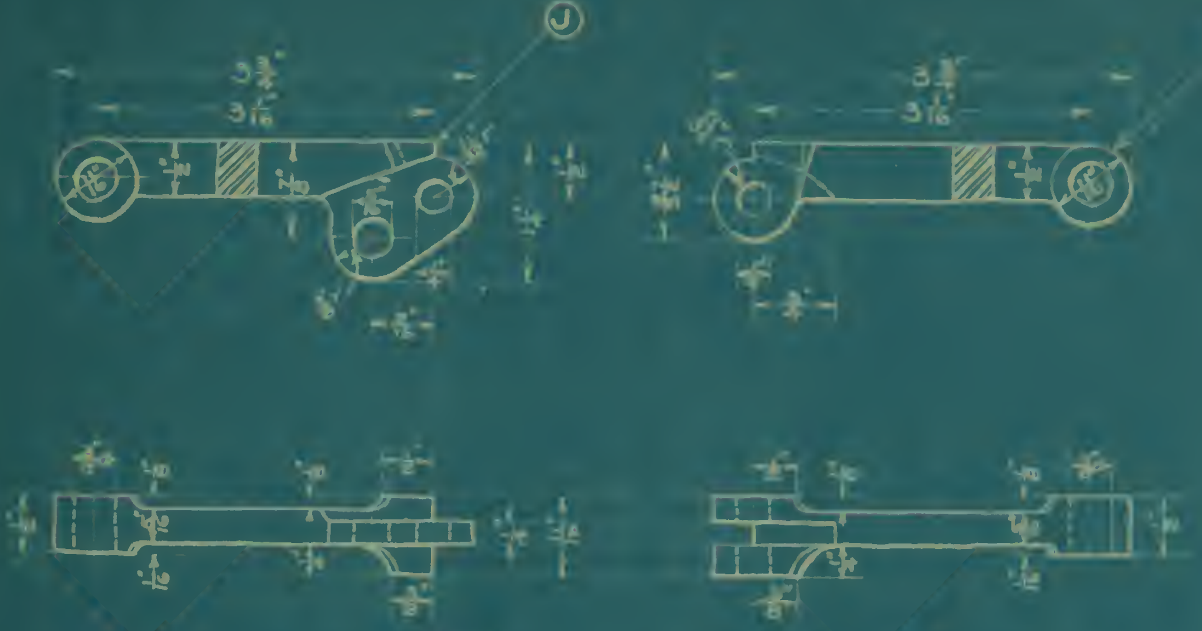
Make Two - C.I.

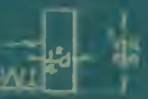
One C with Set-Screw

One D with Oil Hole

DETAILS OF
SMALL COUNTER SHAFT

Scale Full Size



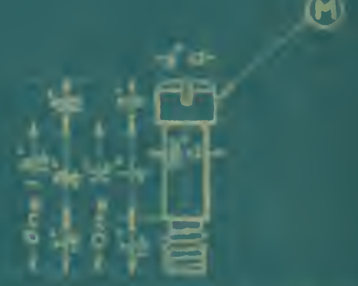


RIVET

Make One - W.I.

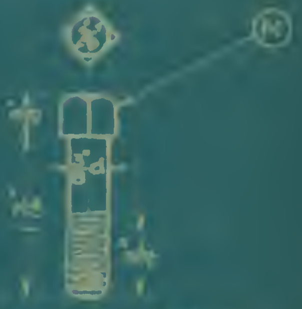
TOGGLE JOINT

Make One - Complete - W.I.



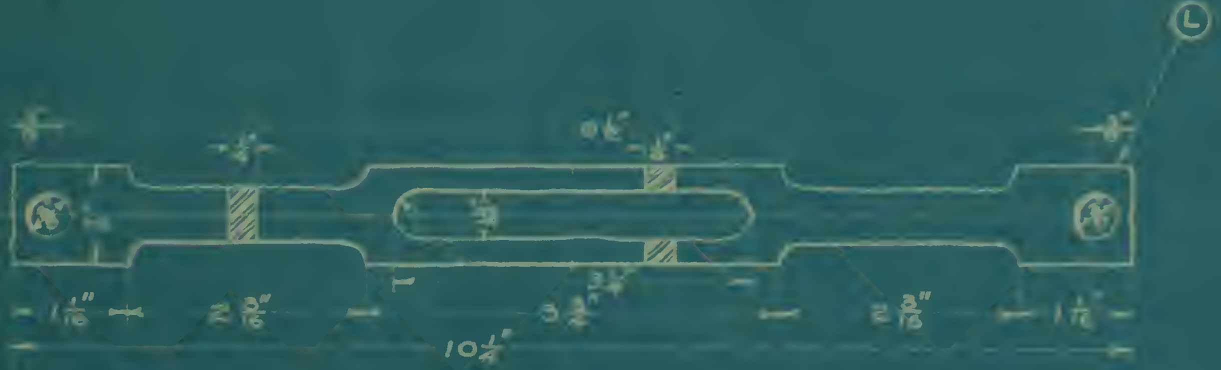
GUIDE PLATE SCREW

Make Two - W.I.



YOKE BOLT

Make One - W.I.



GUIDE PLATE

Make One - W.I.

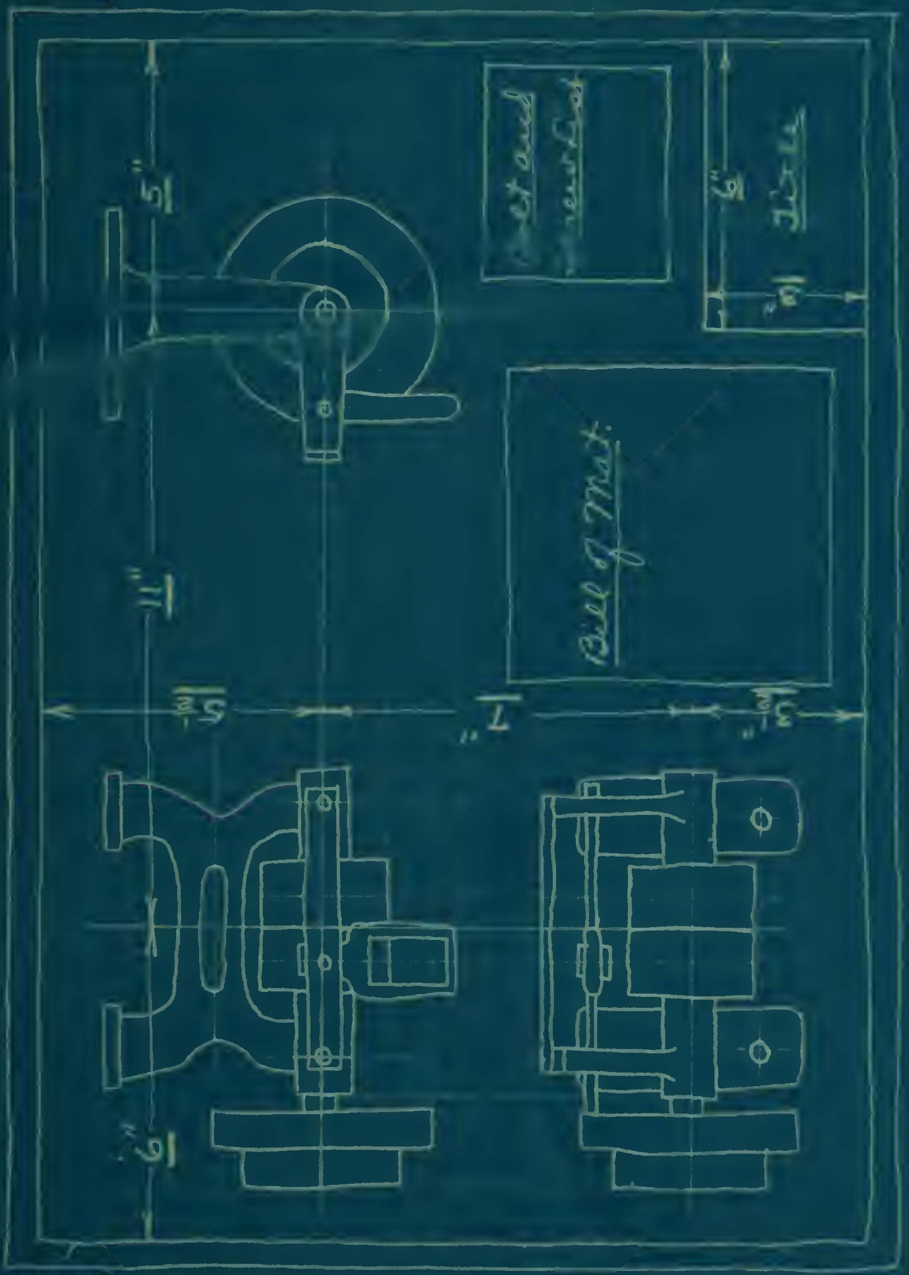
DETAILS OF
SMALL COUNTER SHAFT

Scale: Full Size

[illegible]

LAYOUT FOR DUPLEX SHEET (25e)

18"x 24" - 1" Border.



Draw this Layout (to conveniently larger Scale) Free-Hand on Sketching Pad.

On Duplex Sheet add Materials, etc as given at right of this page.

BILL OF MATERIAL

MARK	NO WANTED	NAME	MAT'L	REMARKS
A	1	Frame	C.I.	
B	1	Cone Pulley	C.I.	with 3/8"x1/2" Set Screw
C	1	Tight Pulley	C.I.	with 3/8"x5/8" Set Screw
D	1	Loose Pulley	C.I.	with Oil Hole
E	1	Shifting Yoke	C.I.	
F	1	Shaft	Steel	Finished Bright
G	1	Shifter Rod	W.I.	
H	1	Spring	Brass	#13 Wire B&S
J&K	1 each	Toggle Joint	W.I.	1/4"x 23/32" W.I. Rivet
L	1	Guide Plate	W.I.	
M	2	Guide Plate Screws	W.I.	1 each as detailed
N	1	Yoke Bolt	W.I.	

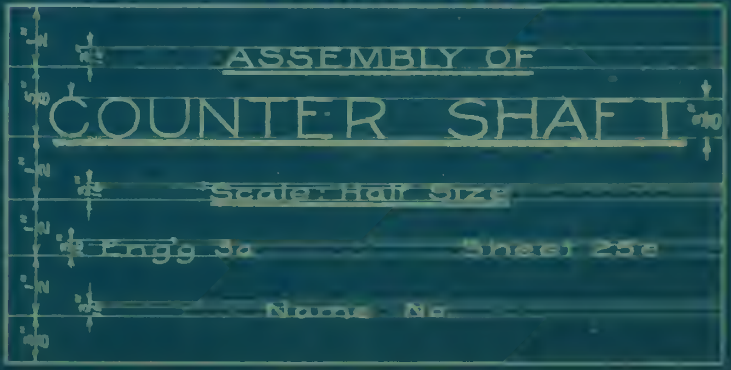
(In Spacing Lines See page 81-2)

BOLT AND SCREW LIST

NO WANTED	DESCRIPTION	MAT'L	FOR
1	3/8"x1/2" Set Screw	Steel	Cone Pulley
1	3/8"x5/8" Set Screw	Steel	Tight Pulley
1	1/4"x23/32" Rivet	W.I.	Toggle Joint
1	3/8"x1 3/16" Cap Screw	W.I.	Guide Plate
1	3/8"x11/16" Cap Screw	W.I.	Guide Plate
1	3/8"x1 7/16" Bolt	W.I.	Yoke

Arrangement of STANDARD TITLE

Frame - 6"x3"



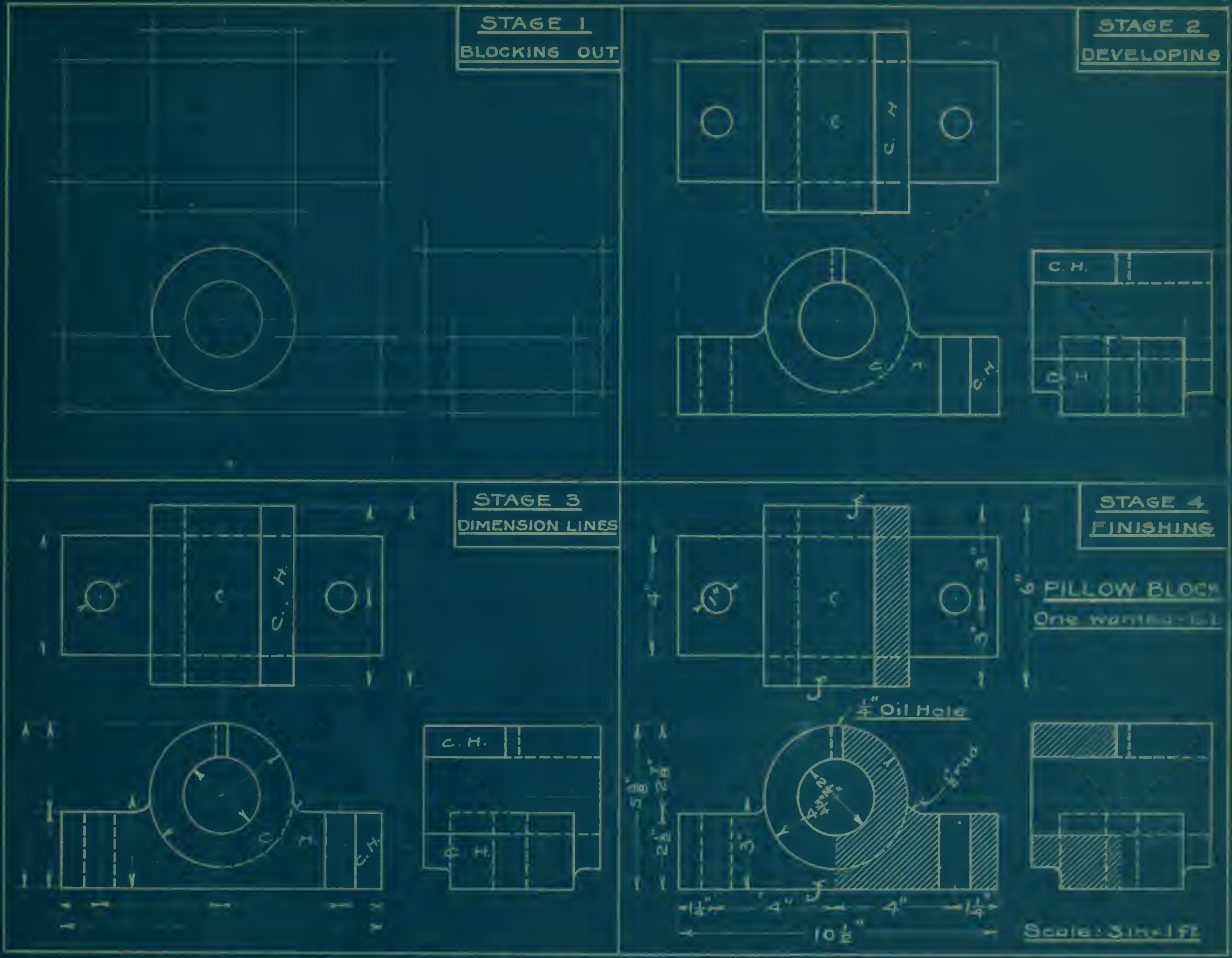
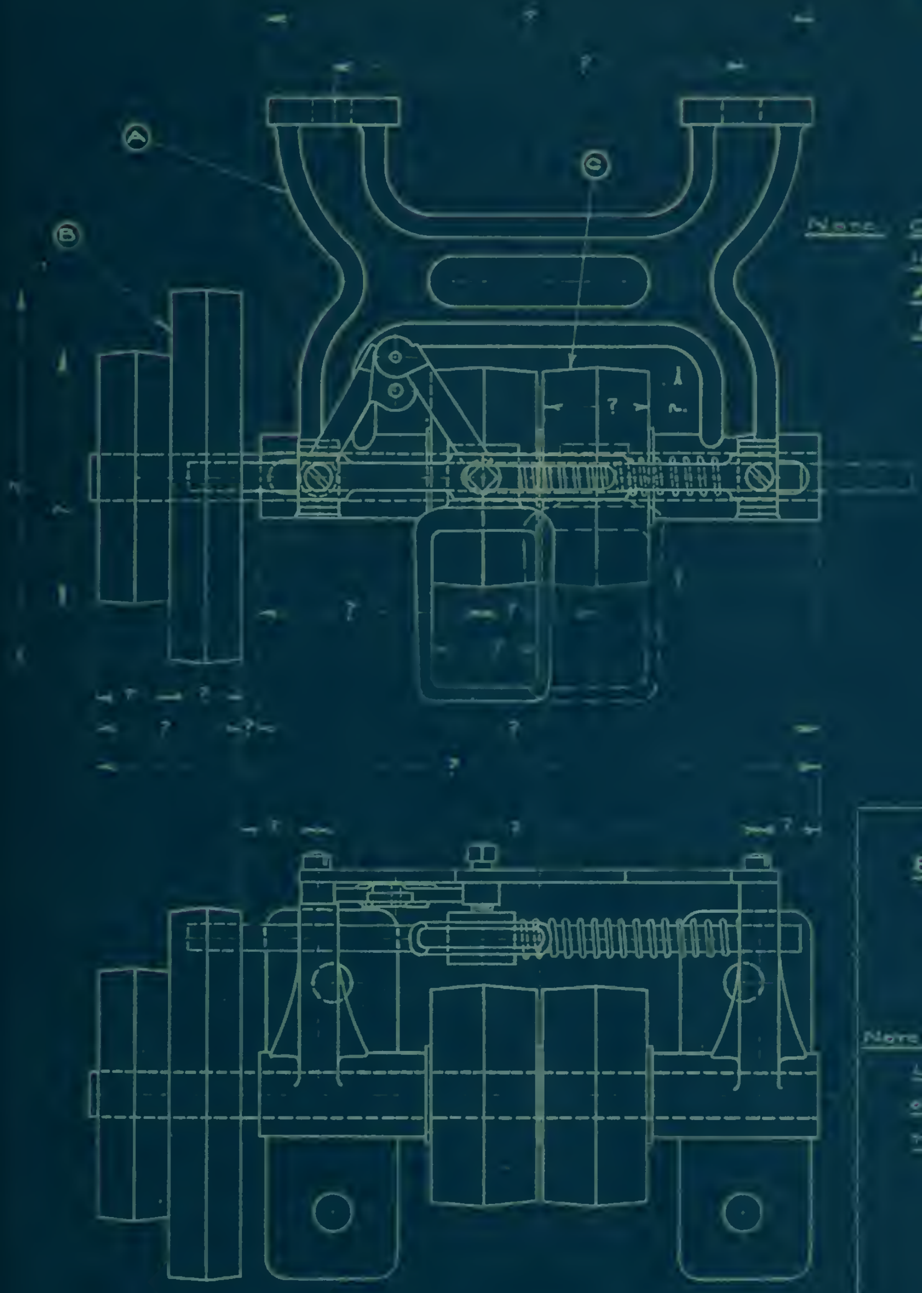


Illustration of 4 STAGES in PENCILLING

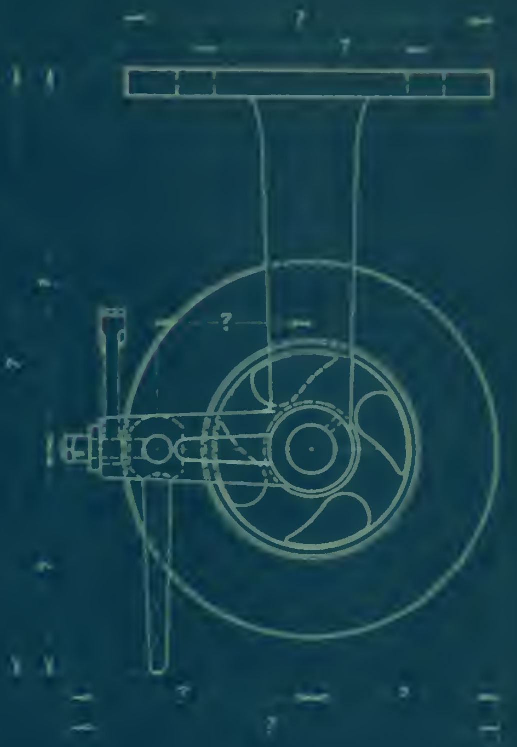
(4 stages in INKING see page 18.)

Pillow Block - Bearing for Shaft or Journal

Sheet E



Note: Continue "Witness" or identifying letters A,B,C etc. as given in Bill of Material

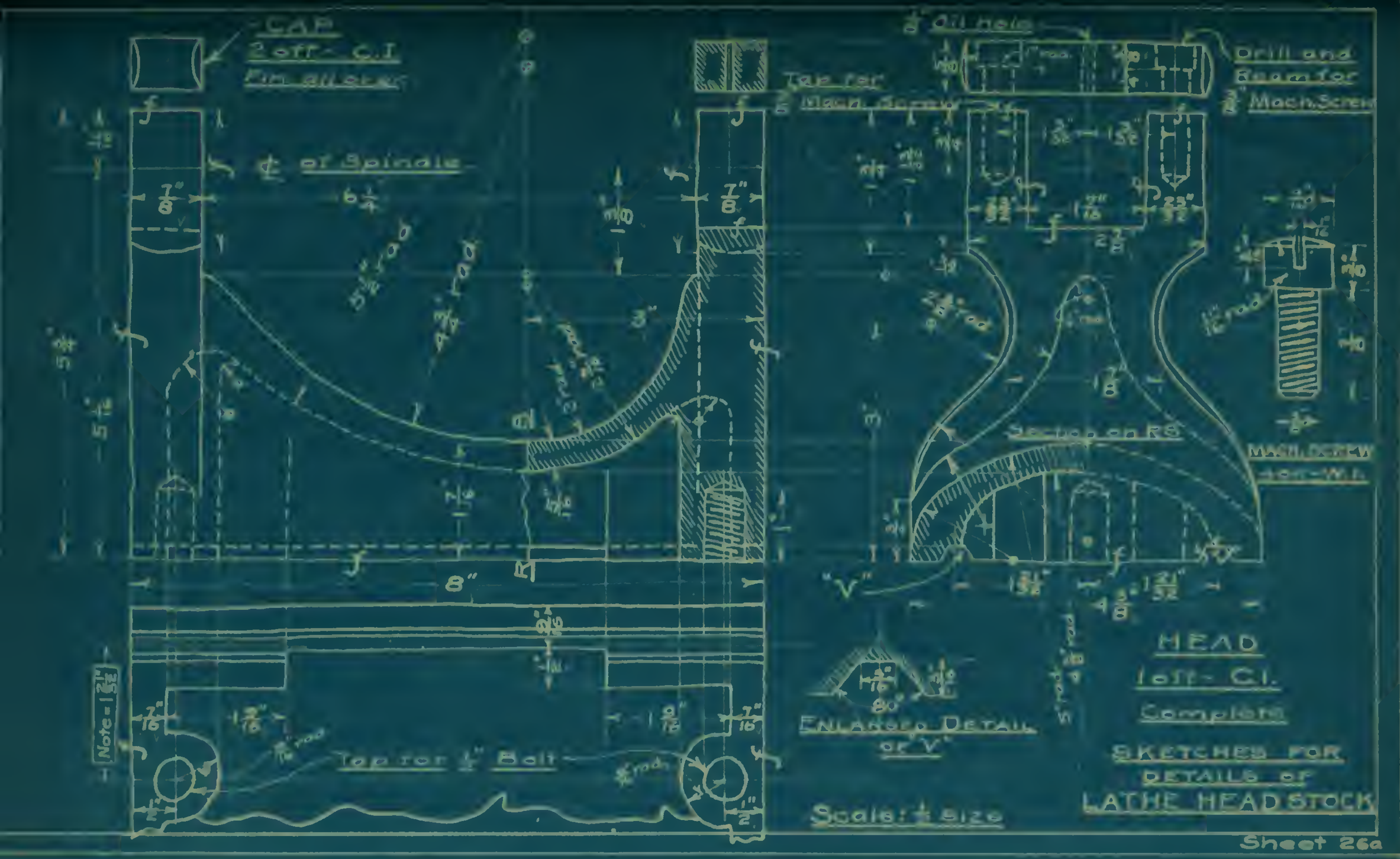


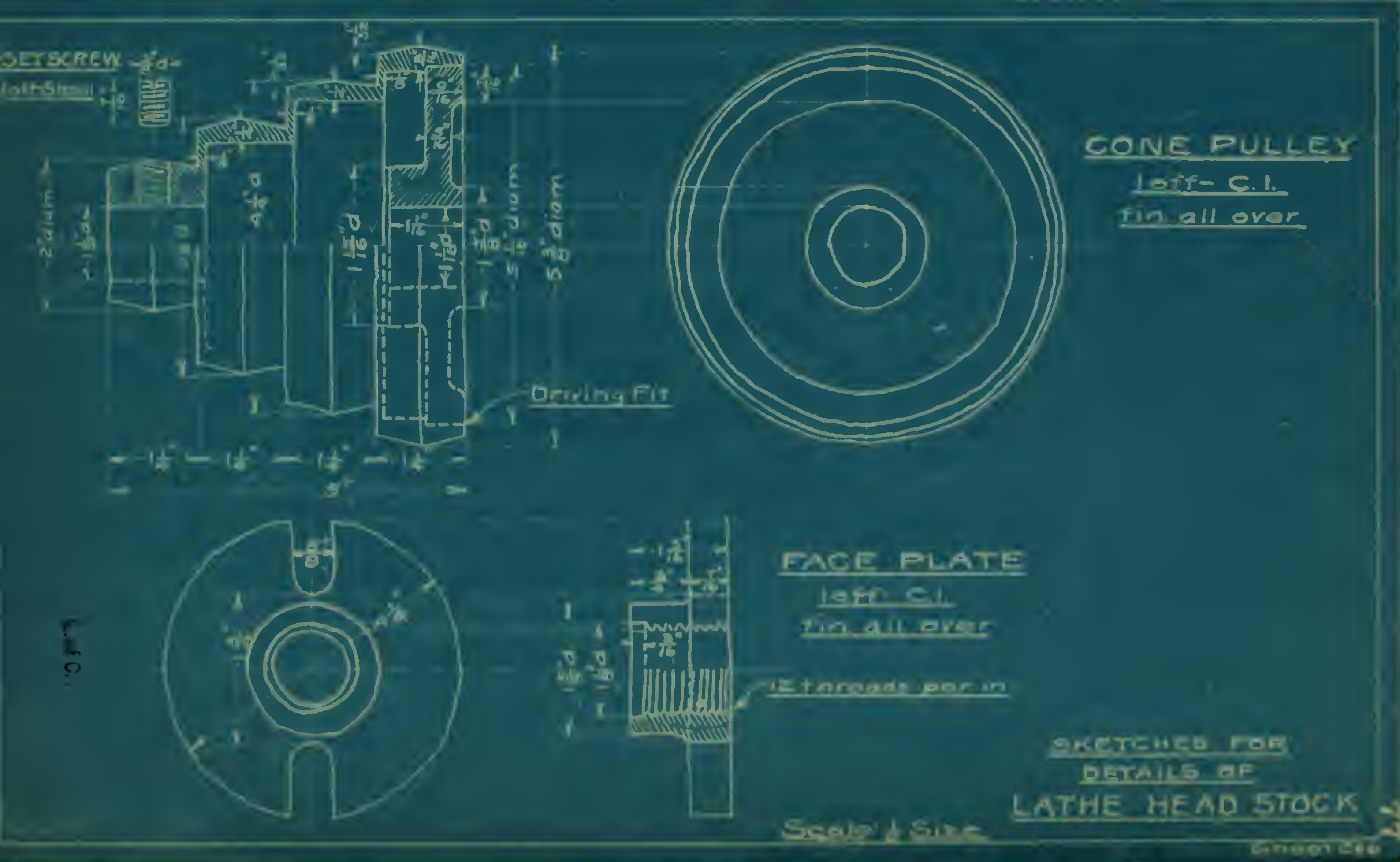
BILL OF MATERIAL
HERE.
SEE PAGE 74.

Note: Use Standard Size Letters and make the arrangement large enough to avoid crowding.

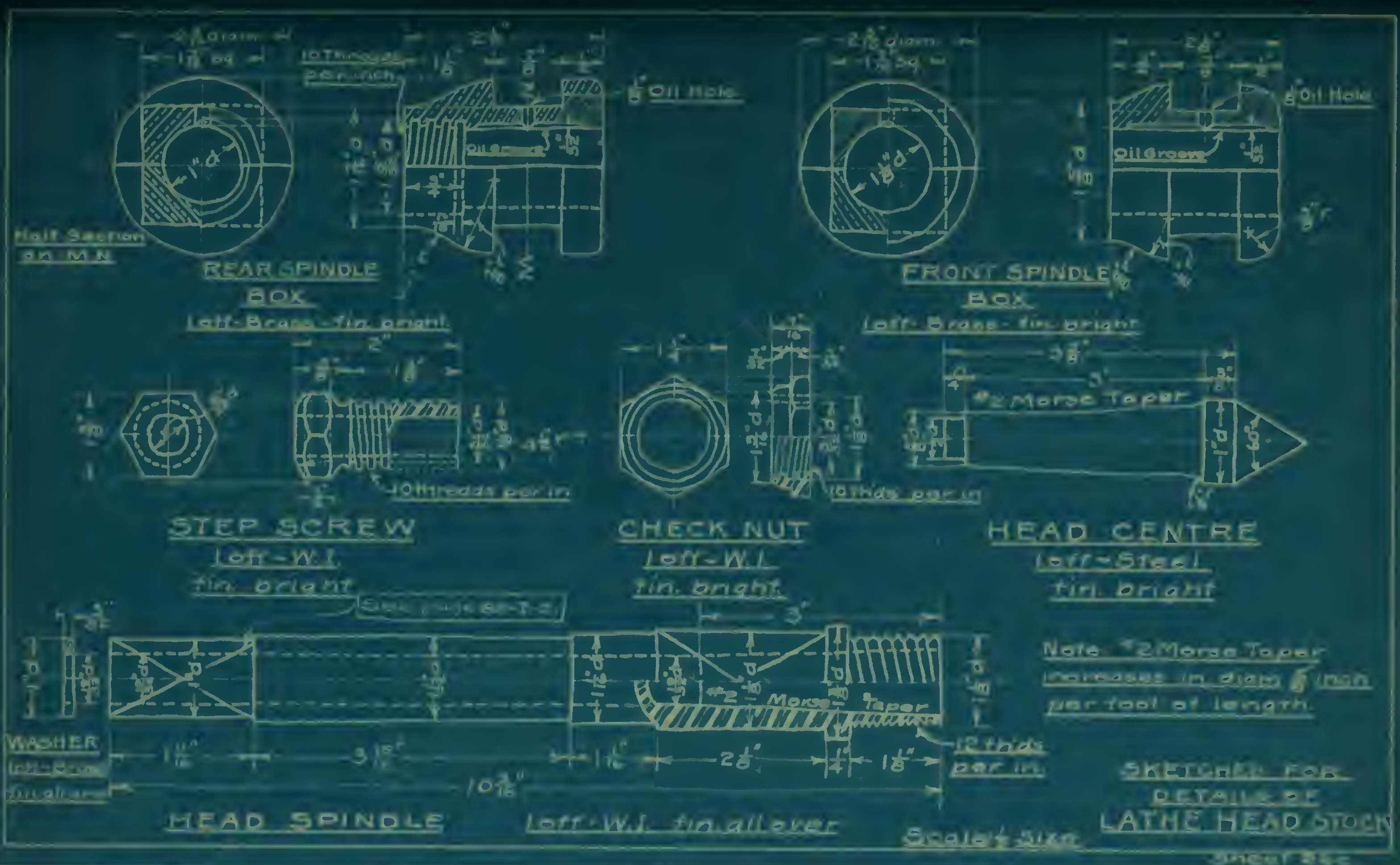
BOLT AND SCREW LIST
HERE
SEE PAGE 74.

STANDARD TITLE
HERE
FRAME 6" × 3"
FOR ARRANGEMENT - SEE PAGE 74

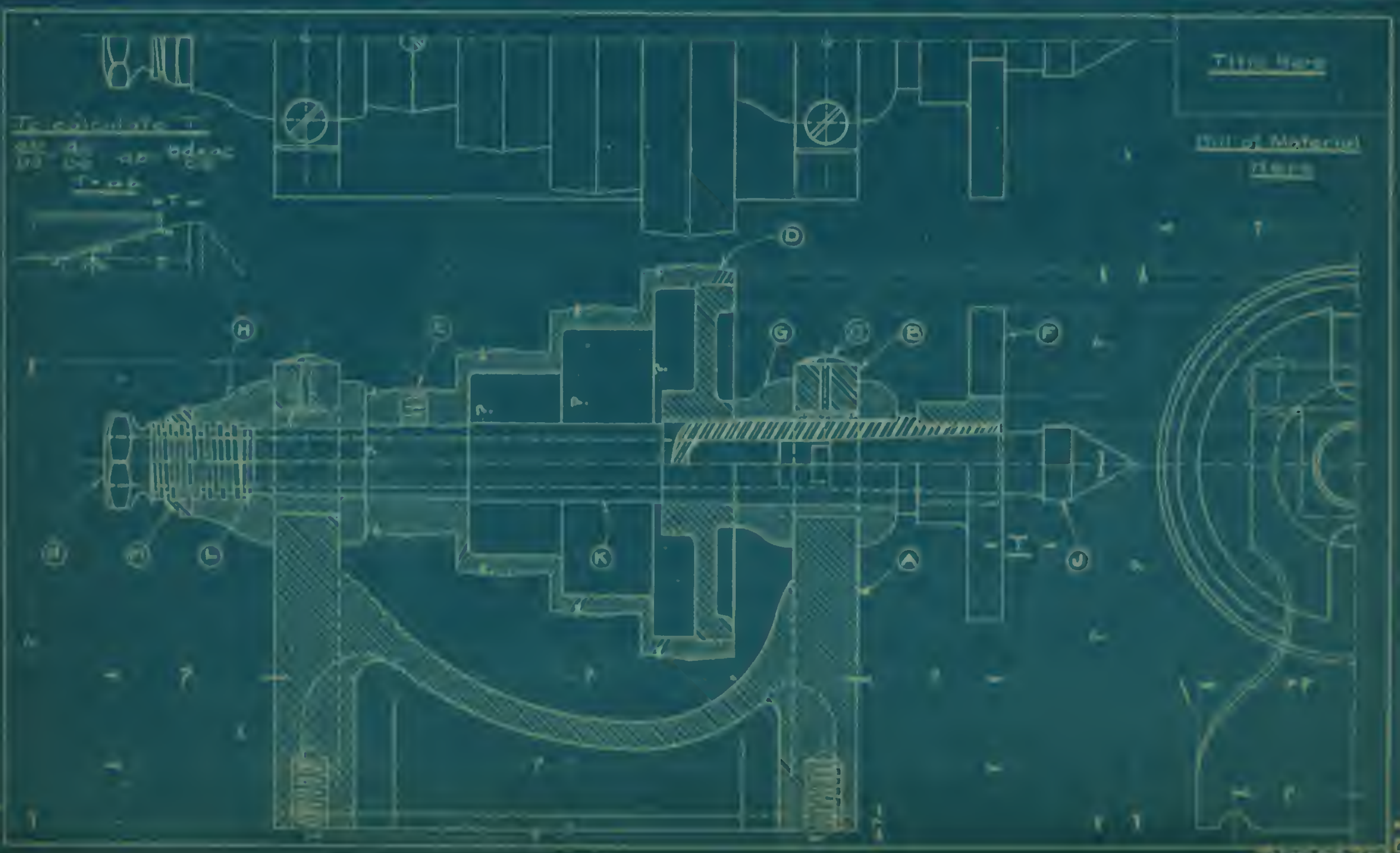

CAP
2 off- C.I.
Fin all over
℄ of Spindle
5½" rad
4¾" rad
8"
R
Tap for ½" Bolt
Note-1 21/32"
Tap for ⅜" Mach. Screw
⅛" Oil hole
Drill and Ream for ⅜" Mach. Screw
Section on RS
MACH. SCREW
4 off-W.I.
"V"
ENLARGED DETAIL of "V"
80°
HEAD
1 off- C.I.
Complete
SKETCHES FOR
DETAILS of
LATHE HEAD STOCK
Scale: ½ Size
Sheet 26a


SETSCREW
1 off-Steel
5⅜" diam
5 1/16" diam
Driving Fit
CONE PULLEY
1 off- C.I.
fin all over
FACE PLATE
1 off- C.I.
fin all over
12 threads per in
SKETCHES FOR
DETAILS OF
LATHE HEAD STOCK
Scale ½ Size
Sheet 26b

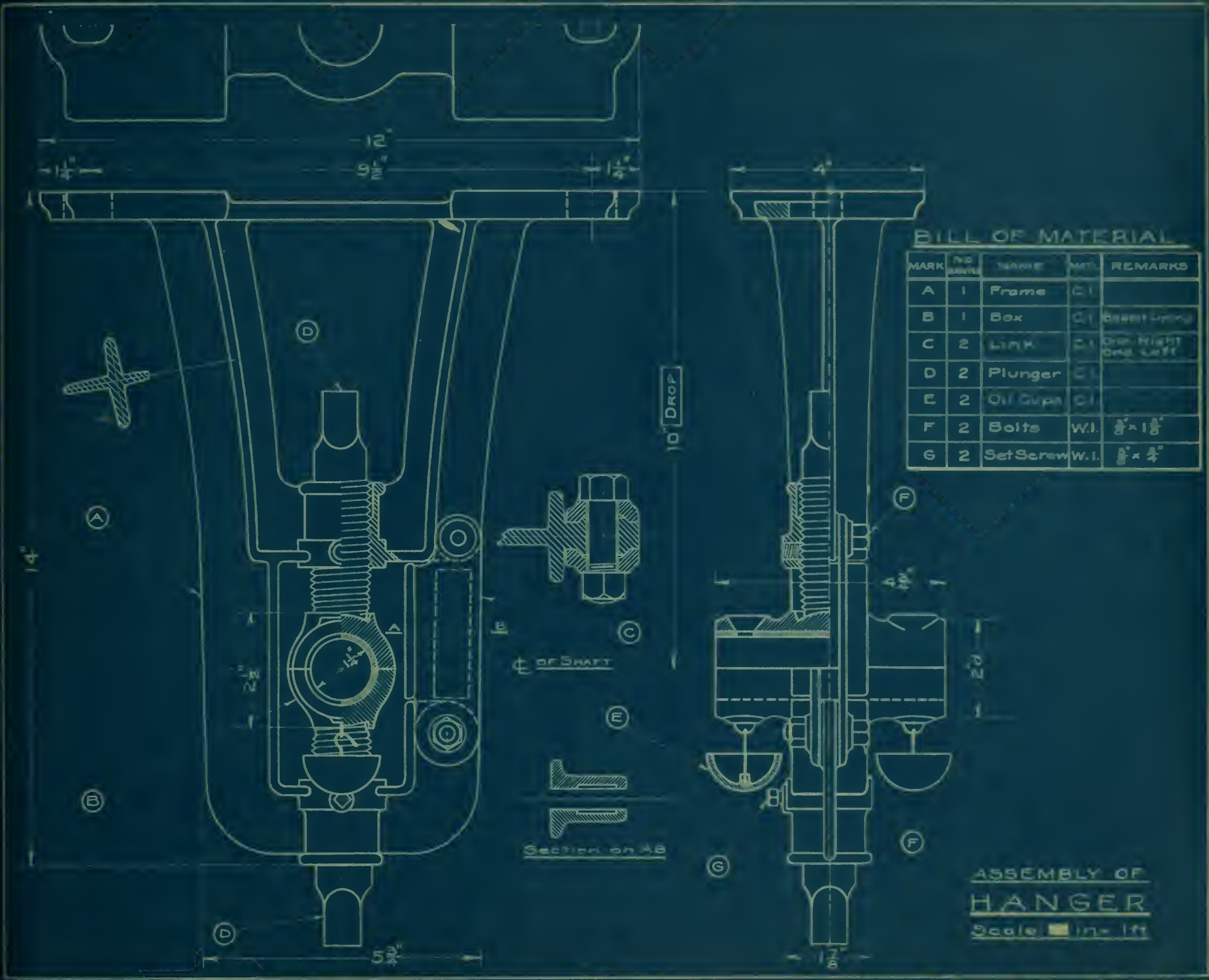
L of C.



Half Section on M.N.
REAR SPINDLE BOX
1 off - Brass - fin. bright
10 Threads per inch
Oil Groove
Oil Hole
FRONT SPINDLE BOX
1 off - Brass - fin. bright
STEP SCREW
1 off - W.I.
fin. bright
10 threads per in
CHECK NUT
1 off - W.I.
fin. bright
10 thds per in
HEAD CENTRE
1 off - Steel
fin. bright
#2 Morse Taper
Note #2 Morse Taper increases in diam. ⅝ inch per foot of length.
WASHER
HEAD SPINDLE
1 off - W.I. fin. all over
#2 Morse Taper
12 thds per in.
Scale ½ Size
SKETCHES FOR DETAILS OF LATHE HEAD STOCK
Sheet 8c



Title Here
Bill of Material Here
To calculate
A
B
C
D
E
F
G
H
J
K
L



BILL OF MATERIAL

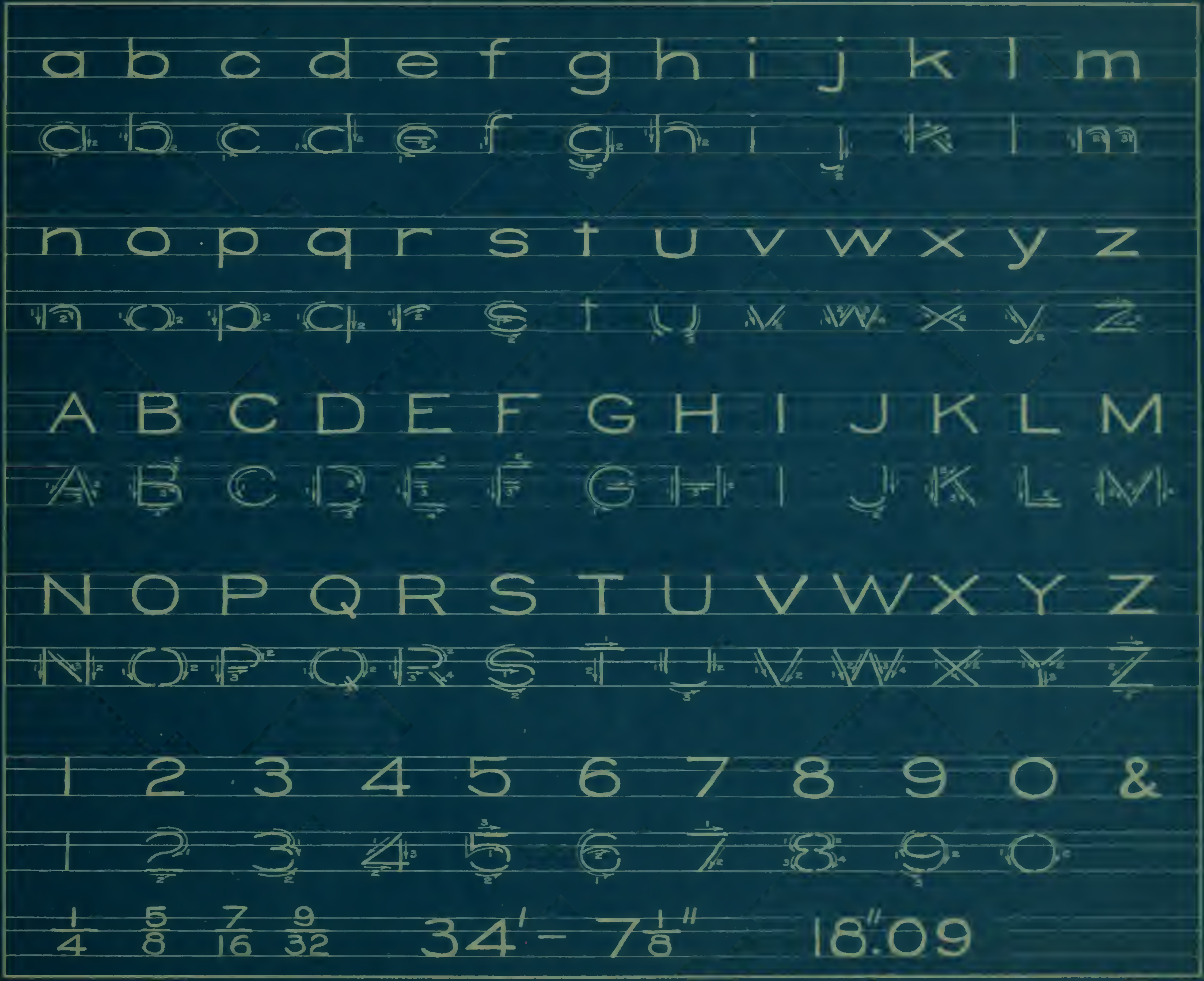
MARK	NO. REQ'D	NAME	MAT'L	REMARKS
A	1	Frame	C.I.	
B	1	Box	C.I.	Babbit Lining
C	2	Link	C.I.	One Right One Left
D	2	Plunger	C.I.	
E	2	Oil Cups	C.I.	
F	2	Bolts	W.I.	$\frac{3}{8}'' \times 1\frac{3}{8}''$
G	2	Set Screw	W.I.	$\frac{3}{8}'' \times \frac{3}{4}''$

ASSEMBLY OF

HANGER

Scale [illegible] in = 1ft

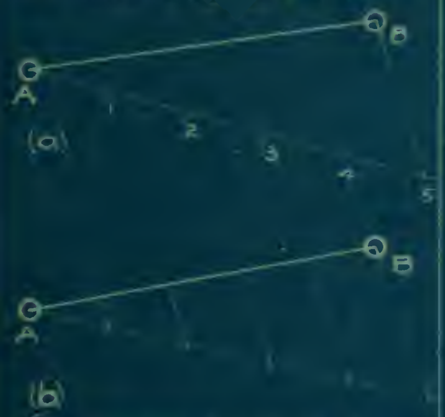
Sheet 27


a b c d e f g h i j k l m
n o p q r s t u v w x y z
A B C D E F G H I J K L M
N O P Q R S T U V W X Y Z
1 2 3 4 5 6 7 8 9 0 &
1/4 5/8 7/16 9/32
34'-7 1/8"
18".09

Sheet F.

GEOMETRICAL CONSTRUCTIONS

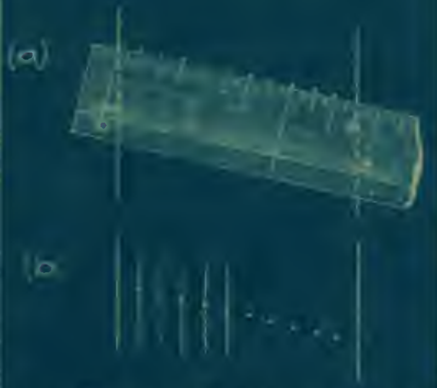
① To divide a line AB into (say) 5 parts



(a) 5 spaces (any size) on A5 (any line). Join 5B.

(b) Lines parallel to 5B give required divisions

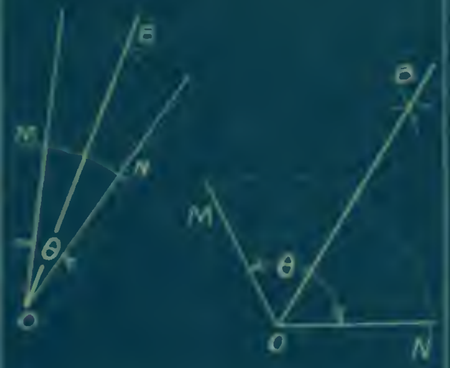
② To divide a space into (say 11 parts) for parallel lines



(a) Point off 11 units any size. Use scale as shown

(b) Draw parallel lines.

③ To bisect an angle θ

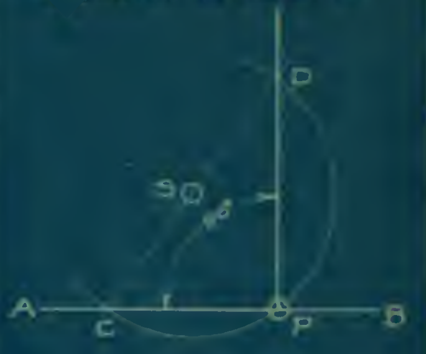


(1) arc MN - any radius

(2) arcs at B - centers at M and N

(3) OB = bisector.

④ To erect a perpendicular to AB at P



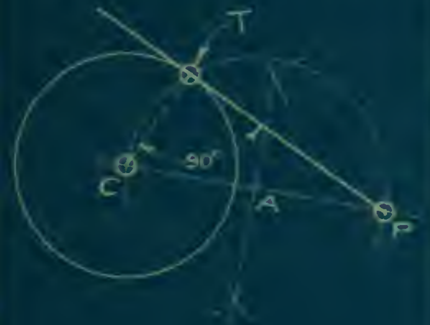
(1) S = any point

(2) Circle thro P. S = center

(3) CD thro S

(4) PD = required perpendic

⑤ To draw a tangent to a circle from a point P.

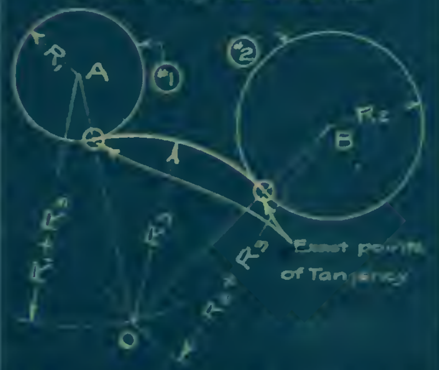


(1) Semi-circle on PC - A = center.

(2) PT = required tangent.

⑥ To draw an arc tangent to 2 given circles, #1 and #2.

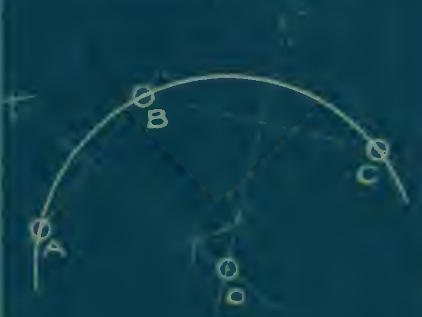
Given R₁, R₂ and R₃



(1) Arcs from A + B meet at O

(2) O = center of required tangent arc.

⑦ To pass an arc thro 3 points, A, B, and C.

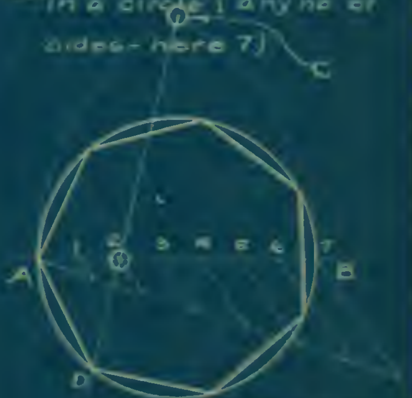


(1) Lines AB and BC

(2) ⊥'s at middle pts meet at O

(3) O = center of required circle

⑧ To inscribe a polygon in a circle (any no. of sides - here 7)



	For	5 sides -	7 sides -	ETC.
(1)	Divide AB into	5 parts	into 7.	ETC

(2) Arcs AC + BC (A + B = centers)

(3) CD always thro second point

(4) AD = required side

Sheet G

SHADING

(Usually in Inking only)

1. To give the effect of RELIEF to a drawing the Convention of Shading is often adopted.
2. The light is assumed to come in the direction of arrows – Fig 1.
3. All Bounding Lines which light does not strike directly are shaded.

   The shaded lines are simply inked Somewhat Heavier than the unshaded to give the effect of casting a shadow.
4. In general, Dotted Lines and Lines representing the intersection of two planes, both of which are visible, are not shaded.
5. SHADING CIRCULAR ARC (Fig 2)

   Draw circle – centre A

   With SAME RADIUS and Centre at B (AB = apprx. 1/32") draw second arc from C to D. Similarly for small circle which represents a hole.

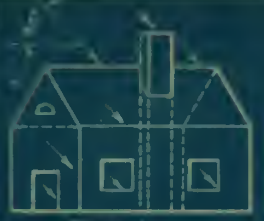


Fig 1

Note: All views of an object are shaded in same manner as above

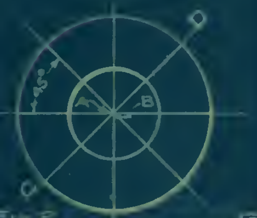
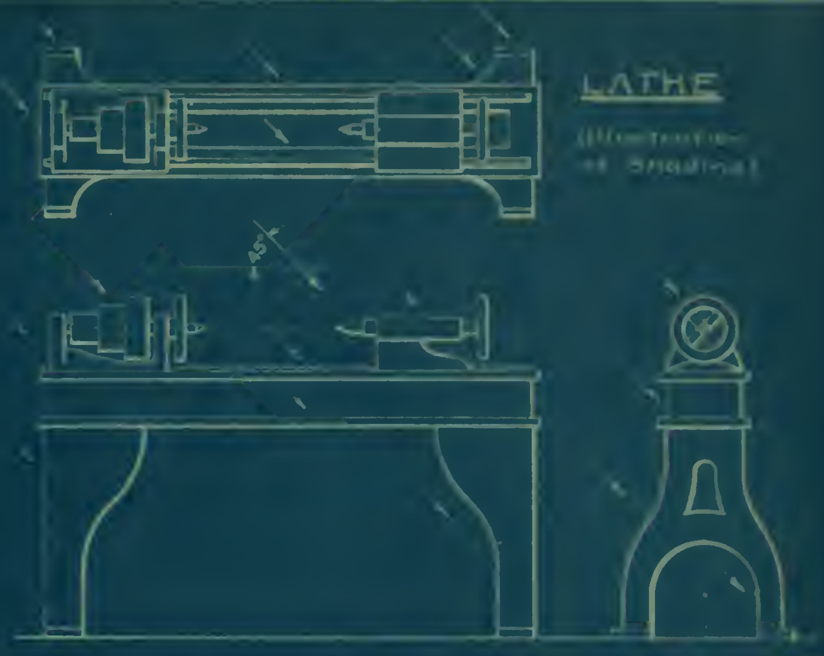


Fig 2

I.



LATHE

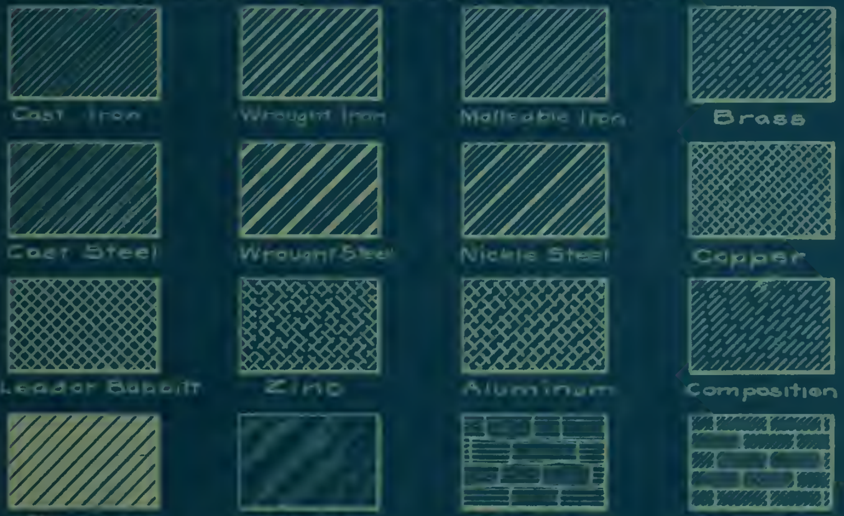
(Illustration of Shading)

II.

SOME CONVENTIONS FOR CROSS SECTIONS

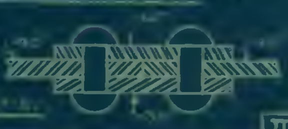
Practice differs – these represent a fair standard.

①



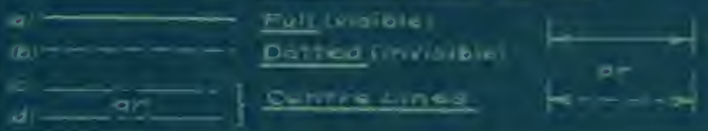
② Usual angle for Crosshatching = 45°

③ Two or more separate pieces in contact, use hatching in different directions.



III.

① TYPES OF LINES



(a) Full (visible)

(b) Dotted (invisible)

(c) or (d) Centre Lines

Dimension and Extension Lines

② NUMBER OF PIECES WANTED

(a) "Two"

(b) "Two of this"

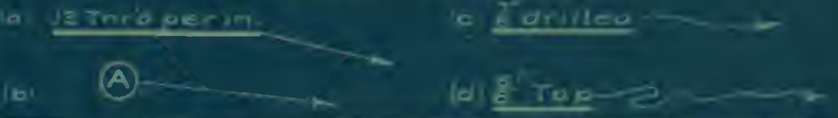
(c) "Make Two"

(d) "2 Off" or "Two Off"

(e) "2 Pieces" or "Two Pieces"

(f) "2 Wanted" or "Two Wanted"

③ WITNESS MARKS



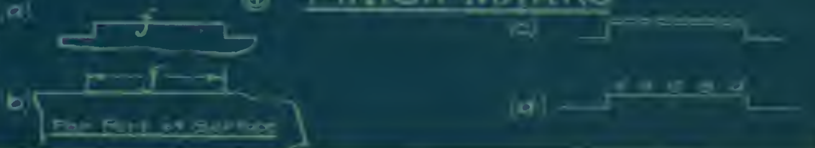
(a) 12 Thr'd per in.

(b) Ⓐ

(c) 1/4" drilled

(d) 3/8" Tap

④ FINISH MARKS



(a)

(b) For Part of Surface

(c)

(d)

IV.

SOME CONVENTIONS

Sheet H

IN GENERAL

(1) First dimension that view which shows details most clearly

(2) Avoid repeating dimensions on a second view.

(3) Dimension where possible to centre lines and finished surfaces

(4) Place dimensions outside of drawing if confusion would result from placing them inside.

(5) Dimension distances only in those views where they appear in their true length

SYMBOLS

(1) 9" = 9 inches 13" = 13 inches etc.

(2) 4' or 4'-0" = 4 feet 5'-6" = 5 feet - 6 inches

(3) Under 2 ft use inches; above 2 ft use feet and inches.

(4) 3" diam. or 3" d. = 3 inches diameter.

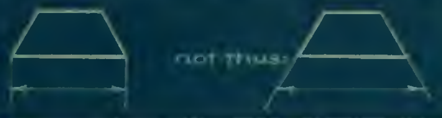
(5) 3" rad. or 3" r = 3 inches radius.

CONVENTIONS AND ILLUSTRATIONS

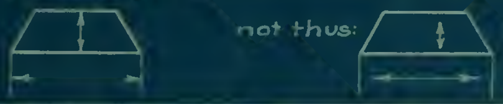
(1) Fractions thus: $\frac{3}{4}''$ not thus: 3/4"

(2) Arrow Points thus: ←—— not thus: ←—— nor {——

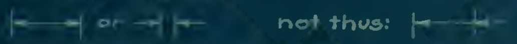
(3) Extension Lines thus: not thus:



(4) Arrow Points always to touch lines dimensioned thus: not thus:

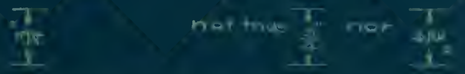


(5) Arrow Points always opposite thus: or not thus:



(6) Horizontal Dimensions thus: $|\leftarrow 2\frac{5}{16}'' \rightarrow|$

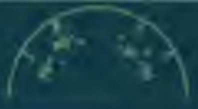
(7) Vertical Dimensions thus: not thus nor



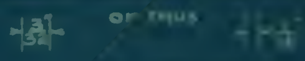
ie (Vertical Dimensions to read from RIGHT)

CONVENTIONS AND ILLUSTRATIONS cont.

(8) Sloping Dimensions thus:

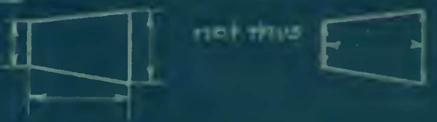


(9) Small Dimensions thus: or thus

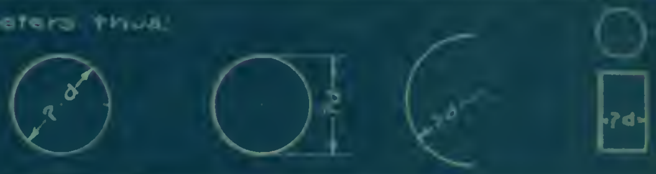


(10) Avoid using LINES OF DRAWING or CENTRE LINES as Dimension Lines

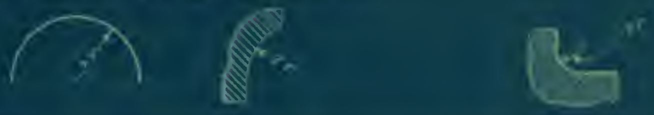
Correct thus: not thus



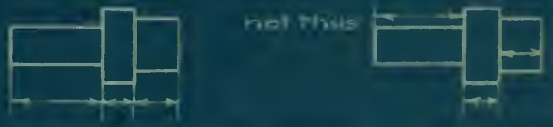
(11) Diameters thus:



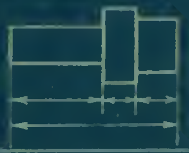
(12) Radii thus: (only one arrow)



(13) Carry Dimensions where possible along one line thus: not thus:



(14) Give Dimension "Over All" as well as subdimensions thus:



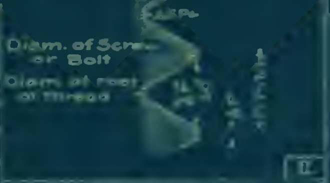
(15) Decimal Dimensions thus: 4."06 not 4.06"

CONCERNING DIMENSIONS

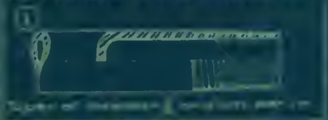
U.S. STANDARD FOR "V" THREADS

Diam. of Screw	Threads per in.	Diam. at root of thd	Diam of Tap Drill
1/4	20	.185	3/16
5/16	18	.240	1/4
3/8	16	.295	5/16
7/16	14	.344	23/64
1/2	13	.400	13/32
9/16	12	.454	15/32
5/8	11	.507	17/32
3/4	10	.620	5/8
7/8	9	.731	3/4
1	8	.837	27/32
1 1/8	7	.940	31/32
1 1/4	7	1.065	1 3/32
1 3/8	6	1.160	1 3/16
1 1/2	6	1.284	1 9/32
1 5/8	5 1/2	1.389	1 13/32
1 3/4	5	1.491	1 1/2
1 7/8	5	1.616	1 5/8
2	4 1/2	1.712	1 3/4
2 1/4	4 1/2	1.962	1 31/32
2 1/2	4	2.176	2 3/16
2 3/4	4	2.426	2 7/16

I.



STANDARD PIPE THREADS

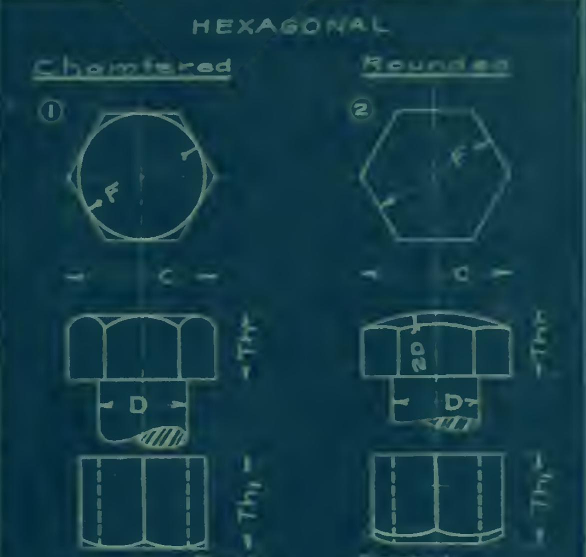


Nominal Size of Pipe	Outside Diam.	Thickness of Metal.	Threads per inch.
1/8	0.405	.068	27
1/4	0.540	.088	18
3/8	0.675	.091	18
1/2	0.840	.109	14
3/4	1.050	.113	14
1	1.315	.134	11 1/2
1 1/4	1.660	.140	11 1/2
1 1/2	1.900	.145	11 1/2
2	2.375	.154	11 1/2

III

U.S. STANDARD BOLTS AND NUTS

HEXAGONAL

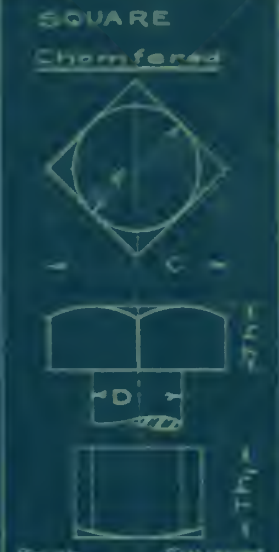


Rough
F = 1½ D + ⅛
C = F × 1.15
Th = ½ F
Th₁ = D

Finished
F = 1½ D + 1/16
C = F × 1.15
Th = ½ F
Th₁ = D − 1/16

IV.

SQUARE



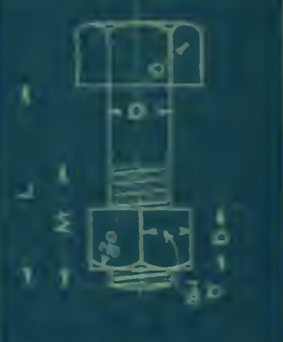
Rough
F = 1½ D + ⅛
C = F × 1.41
Th = ½ F
Th₁ = D

Finished
F = 1½ D + 1/16
C = F × 1.41
Th = ½ F
Th₁ = D − 1/16

V.

CONVENTIONAL METHOD

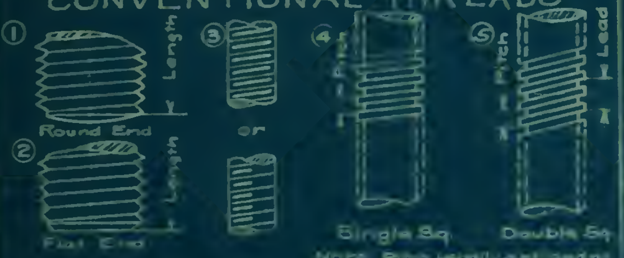
OFTEN USED IN DRAWING SMALL HEXAGONAL BOLTS



Necessary Dimensions = D.L.M.

VI.

CONVENTIONAL THREADS



Note: Pitch usually defined as 8 threads per inch, 10 per 1 in., etc.

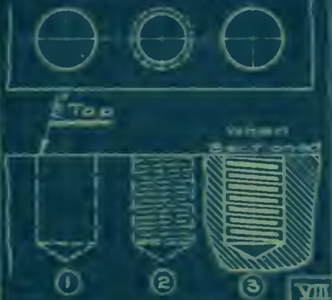
For Large "V" Threads

For Small "V" Threads

VII.

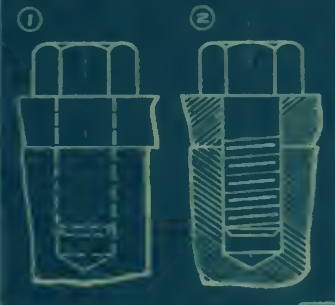
TAPPED HOLES

THREE METHODS



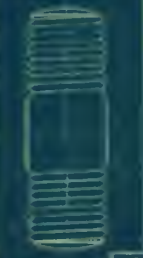
VIII

BOLTS IN PLACE



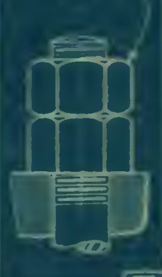
IX.

STUD BOLT



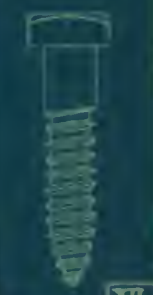
X

CHECK NUT



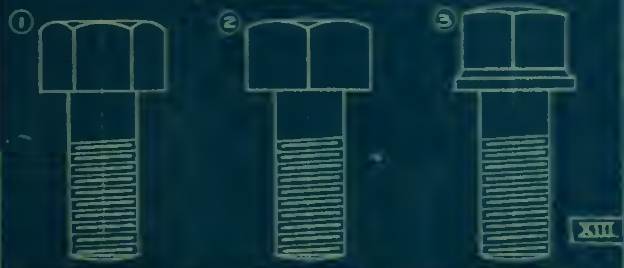
XI.

LAG SCREW



XII.

CAP OR TAP BOLTS



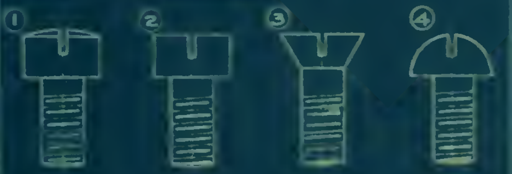
Hexagonal Head

Square Head

Collared

XIII

CAP OR MACHINE SCREWS



Fillister Head

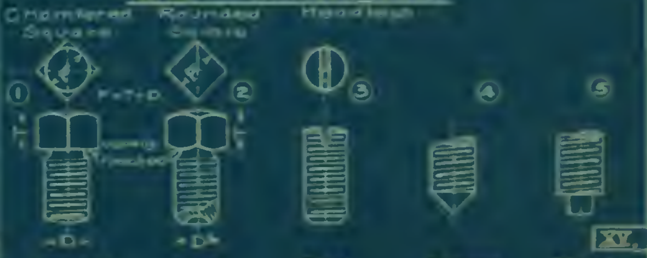
Round or Cheese Head

Flat or Countersunk

Button Head

XIV.

SET SCREWS



Round Point

Cup Point

Flat Point

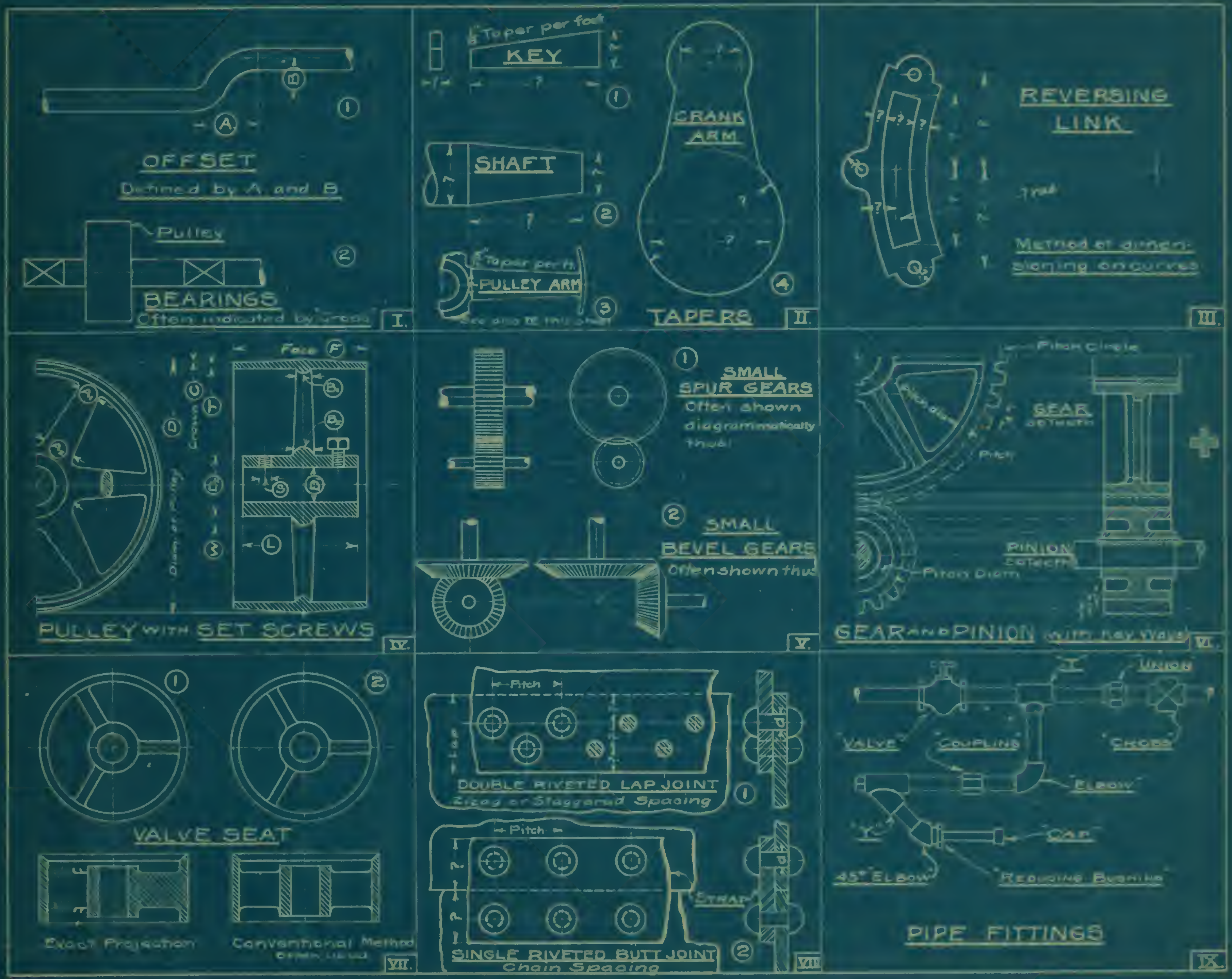
Cone Point

Pivot Point

XV.

References: — Reid, Elem. Mach. Des. Chap. I — Bartlett Mach. Draw. pp. 55-76 — Anthony Mach. Drawing Chap. I

Sheet K



SOME CONVENTIONS IN DIMENSIONING AND DRAWING

Sheet L

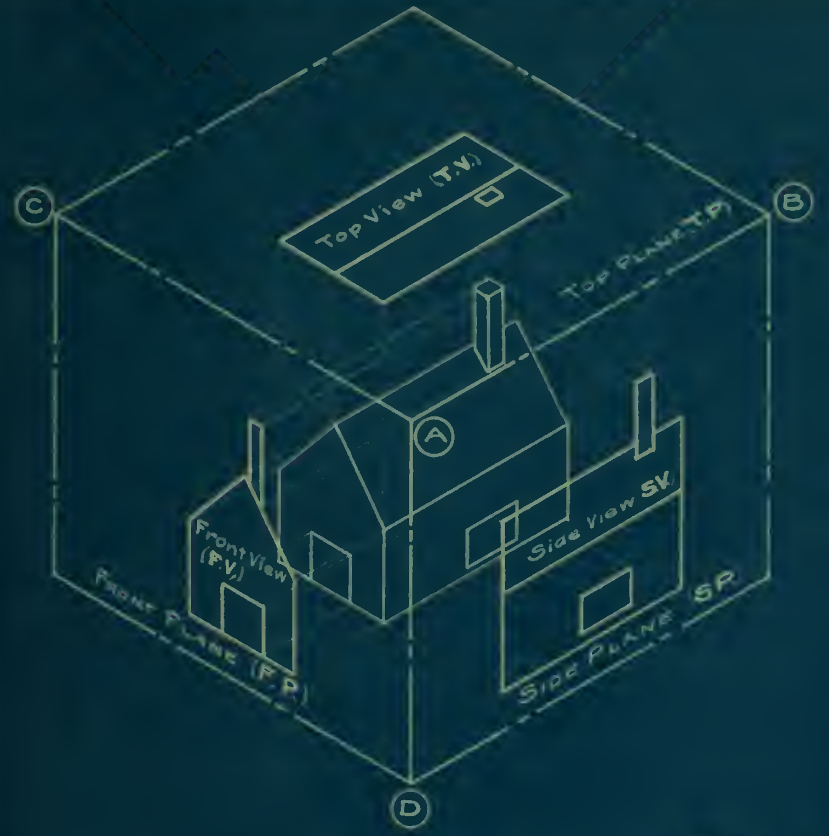


Fig. 1

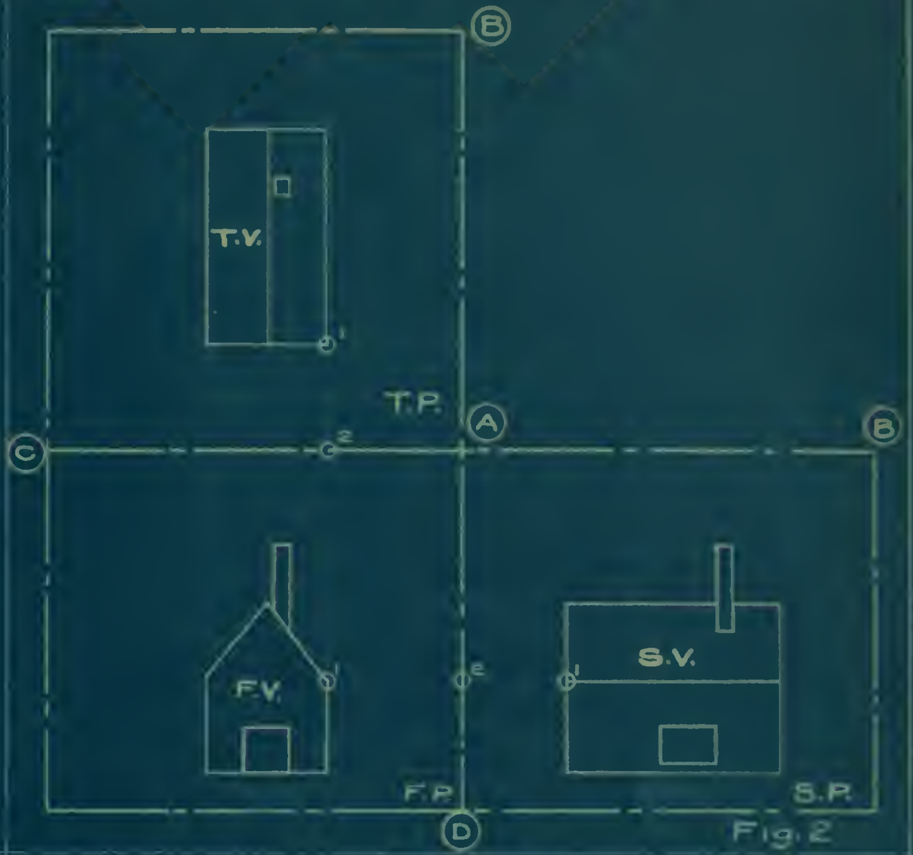


Fig. 2

1. Consider object surrounded by THREE PLANES, F.P., S.P., and T.P. as shown (Fig. 1). These planes are called "PLANES OF PROJECTION"

2. Let rays perpendicular to each plane respectively, pass from every point of object to these planes.

3. The intersection of these rays and their respective planes will trace Three Views, F.V., S.V. + T.V. as shown (Fig. 1).

4. These views are called the "PROJECTIONS"* of the object.

* Note: (a) More accurately, the "ORTHOGRAPHIC PROJECTIONS" because the rays make RIGHT ANGLES with their respective planes – ὀρθός = Right + γράφειν = to Draw.
(b) By additional planes a BOTTOM VIEW, a LEFT SIDE VIEW and a REAR VIEW can be obtained.

5. Consider the PLANES OF PROJECTION to be separated along **AB**. Turn **T.P.** on **AC** and **S.P.** on **AD** and spread all three planes out flat. The resulting location of the views will be as in Fig. 2.

6. Note that a. T.V. is above F.V., and S.V. at side of F.V.§
b. Point 1 in T.V. is VERTICALLY over point 1 in F.V.
c. Point 1 is on same HORIZONTAL LINE in S.V. and F.V.
d. Distance 2,1 in S.V. = distance 2,1 in T.V.
These 4 relations are true for all corresponding pts in the 3 Views.

7. The above principles apply to the representation of all objects by the method of ORTHOGRAPHIC PROJECTION.

§ Note: F.V. often called FRONT ELEVATION.
S.V. " " SIDE ELEVATION.
T.V. " " PLAN.

ORTHOGRAPHIC PROJECTION

Sheet M.

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